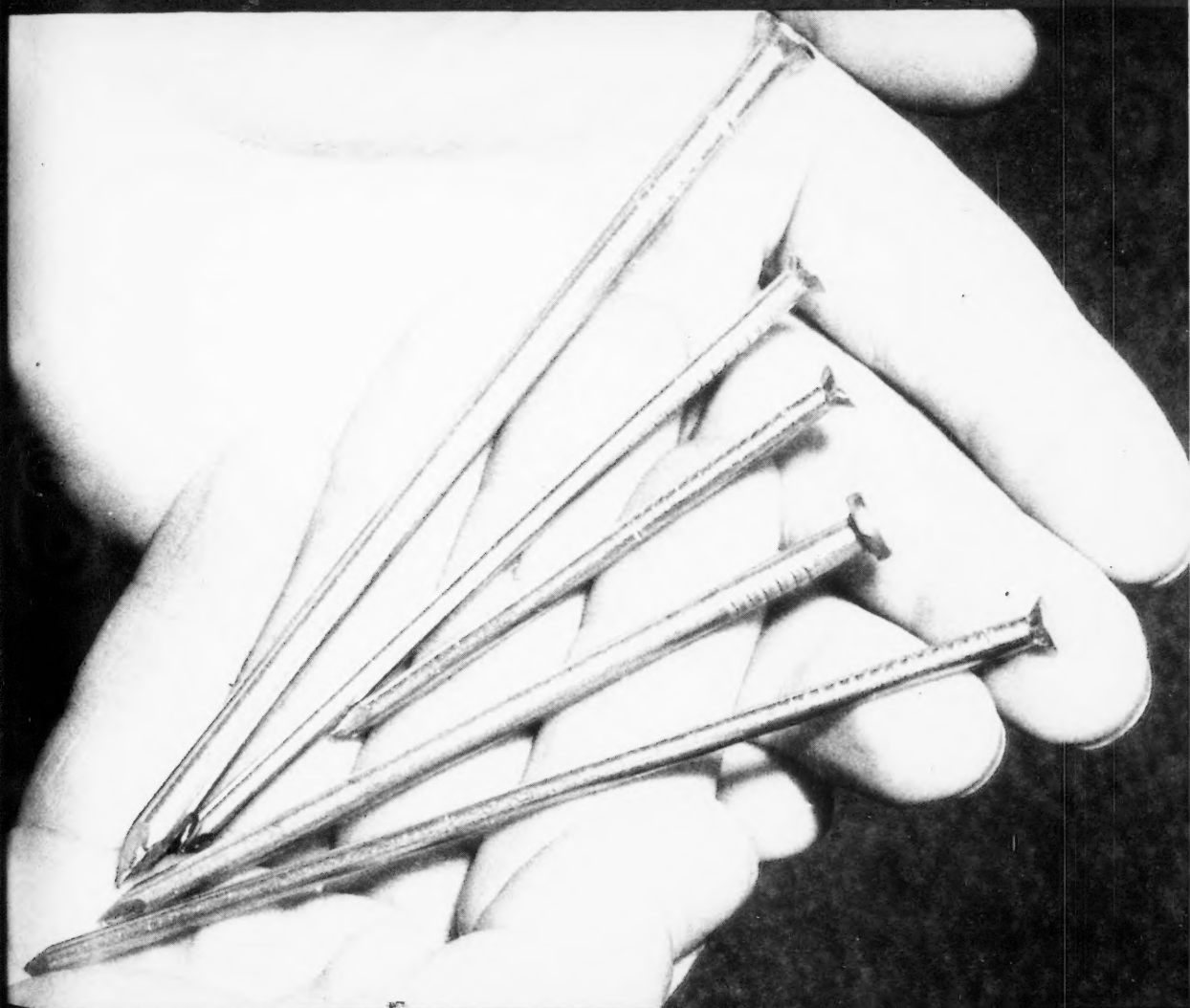


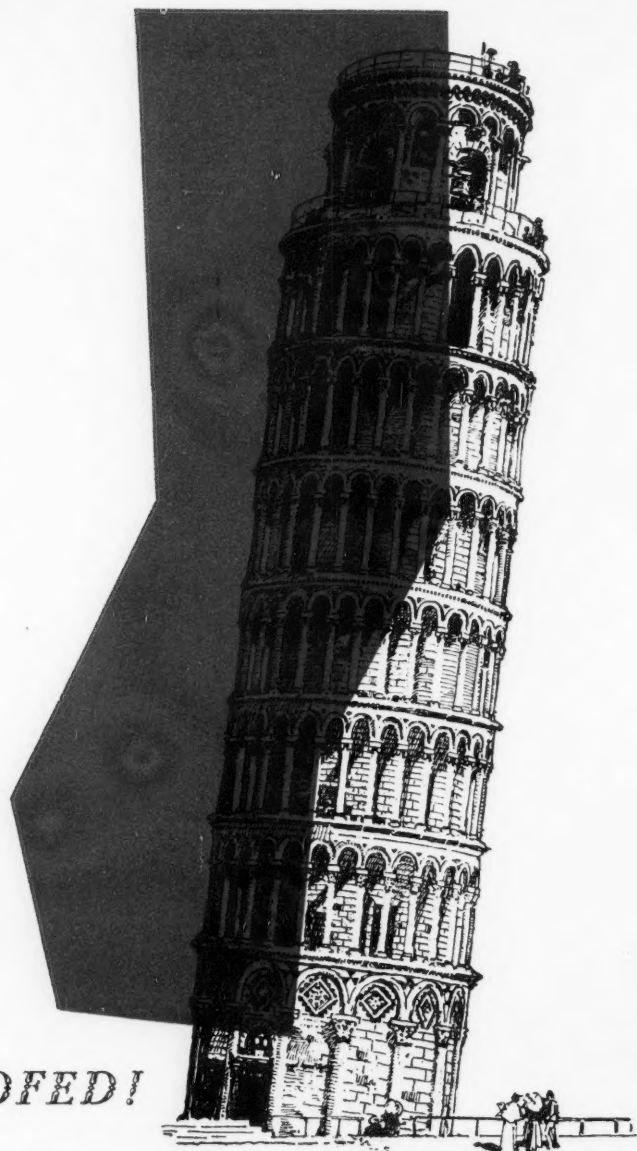
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



NOVEMBER, 1956

No. 11



SOMEBODY GOOFED!

Only by a freak of fortune does the leaning tower of Pisa still stand. A faulty foundation was not apparent until the structure was three stories high. It is believed the architects were then forced to compensate by adding weight to the opposite side to save the building.

Are you building corrosion problems into your plant structures and equipment that will inevitably have to be compensated for by tremendous replacement costs? Many of these costs can be eliminated *at the planning stage* by taking advantage of the services of an expert in the field of corrosion resistant coatings... the Amercoat Sales Engineer.

The Amercoat Sales Engineer is trained in the principle that in corrosion engineering, too, foundations are all-important. You can put this factory-trained man on your staff, so to speak, without cost or obligation. His advice will be truly objective since it is based on a knowledge of all types of protective coatings and more than 43,000 case histories in our files. You can be sure that the Amercoat coating he recommends, whether vinyl, phenolic, epoxy or any other type, will be the right one for *your* job, and the most economical on the basis of cost per square foot per year.

Therefore, to effect important economies in specifying protective coatings you are cordially invited to call on your Amercoat Sales Engineer... *right at the beginning*. He will analyze all per-

tinent data concerning your corrosion problems based on our nearly 20 years of corrosion control experience, and give you a comprehensive recommendation. In addition to recommending the proper coatings, he will assist you in writing complete specifications. However, this is not the full extent of his service: he will also be available for consultation at the job site to insure proper application.

There are more than 70 Amercoat Sales Engineers and Distributors located throughout the country. It will pay you to talk to one of these men whether you are building a new plant or are interested in the efficient maintenance of existing facilities. The same service is available and equally important savings can be realized in both cases.

May we send you the name of the Amercoat man nearest you? Literature containing many helpful suggestions for the design and corrosion engineer is also available on request. Write to: Amercoat Corporation, 4809 Firestone Blvd., South Gate, Calif.

"Follow the Line of
MOST Resistance"

Amercoat

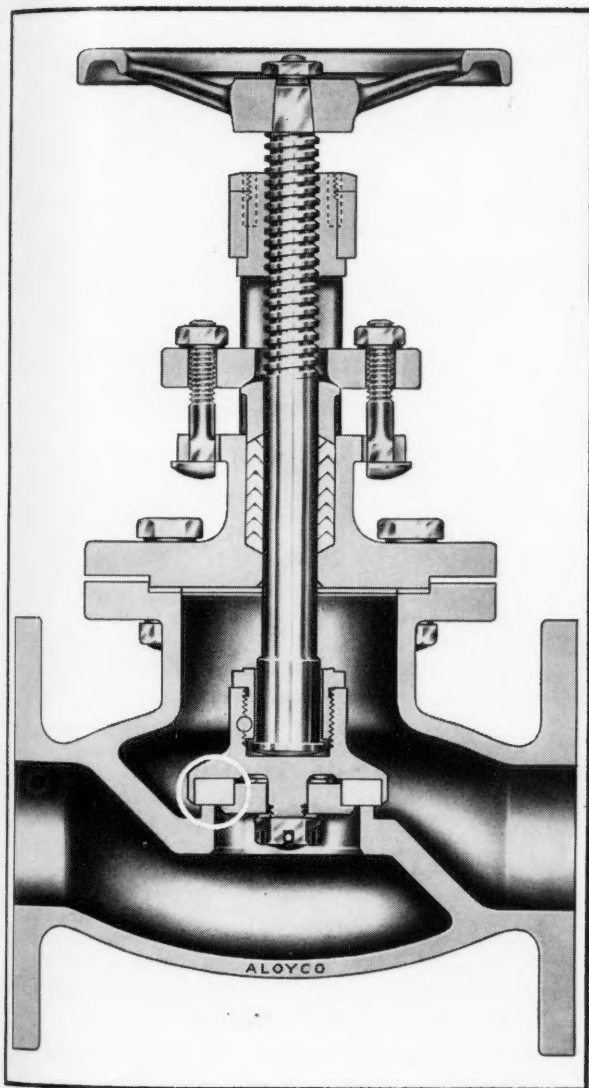
CORPORATION Dept. GK,

4809 Firestone Blvd., South Gate, Calif.

Houston, Texas • Jacksonville, Florida • Evanston, Illinois • Kenilworth, New Jersey

Teflon* forms gas-tight seal in corrosion resistant Aloyco valves

*Registered DuPont trademark.



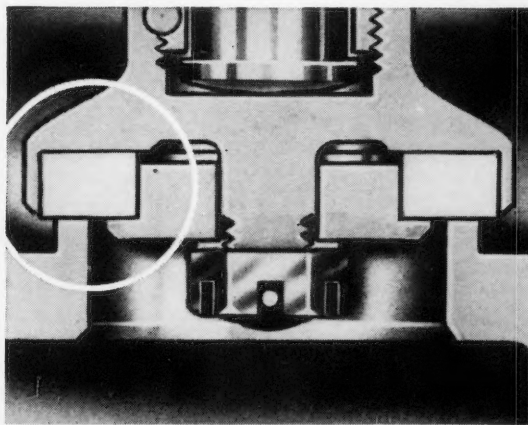
Hard-to-hold volatile or elusive fluids—even if highly corrosive—can't leak past the Teflon discs or packing in this Aloyco valve.

The reason? Teflon's ability to form a gas-tight seal under compression—even when the seating surface or adjoining metal is slightly corroded. That's why Teflon-equipped valves outlast and outperform valves with metal-to-metal seating surfaces in handling volatile corrosive fluids.

Add to that the fact that Teflon has high impact strength under hydraulic shock loads, and is inert to almost all chemicals up to 500° F., and you'll see why Aloyco pioneered the use of this unique material for discs, seats and packing in corrosion-resistant valves.

Aloyco valves with renewable Teflon discs, seats, and packing come with screwed or flanged ends in a variety of styles: globe, Y, angle, swing-check, needle, plug-gate—as well as sampling valves. You'll find them all described in our new bulletin No. 11. Mail coupon below for your copy.

6.4



ALOYCO GLOBE VALVE holds Teflon disc securely against possible overload.



Alloy Steel Products Company, Inc.
1304 West Elizabeth Avenue
Linden, New Jersey

Gentlemen:

Please send me a free copy of your new Bulletin No. 11 on Aloyco valves with renewable Teflon discs or seats.

Name _____

Firm _____

Address _____

City _____ Zone _____ State _____

d on our
give you
mmending
ete speci-
ervice: he
to insure

and Dis-
ou to talk
ant or are
ities. The
ys can be

rest you?
ne design
Write to:
te, Calif.

Dept. GK,
Gate, Calif.
New Jersey

MAGNESIUM for cathodic protection



A sample of every melt is rushed to the lab for spectrographic analysis via a pneumatic tube similar to those in department stores.

Spot check? No sir—Each Magnesium Anode is QUALITY CONTROLLED

Quality control is no idle phrase at Dow's Madison, Illinois, mill. Every magnesium anode produced there meets rigid production requirements before it goes out into the field. And because quality is consistently high, users of Dow magnesium anodes get consistent results in terms of better cathodic protection.

Here's how it works: A sample of every melt is analyzed by spectrograph before pouring. The sample is dispatched

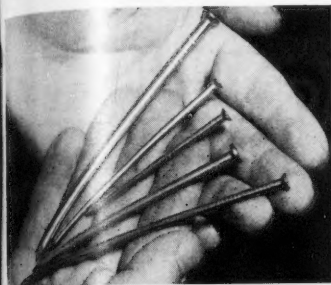
to the lab by means of a pneumatic tube system. An immediate check is made and results are phoned back to the foundry before the O.K. to pour is given.

More effective protection. All this adds up to more effective, more dependable protection. Any of the Dow anode distributors listed below can show you big savings for your specific applications. Call one today. THE DOW CHEMICAL COMPANY, Dept. MA 379P, Midland, Michigan.

CALL THE DISTRIBUTOR NEAREST YOU: Cathodic Protection Service, Houston, Texas • Corrosion Services, Inc., Tulsa, Oklahoma • Electro Rust-Proofing Corp. (Service Division), Belleville, N. J. • Ets-Hokin & Galvan, San Francisco, Calif. • Royston Laboratories, Inc., Blawnox, Penna. • Stuart Steel Protection Corp., Plainfield, N. J. • The Vanode Co., Pasadena, Calif.

you can depend on DOW MAGNESIUM ANODES





THIS MONTH'S COVER—These may look like garden variety nails nearly everyone is familiar with—but they emphatically are different. John Hassall, Inc., Westbury, L. I. makes nails like these of Hastelloy alloy C for fabrication and repair of wooden vats holding strong corrosives. They are used extensively in the paper making and atomic energy industries.



EDITORIAL STAFF

IVY M. PARKER—Editor

Editorial Review Committee

E. V. KUNKEL—Chairman

FRANKLIN H. BECK	J. J. HARWOOD
GEROME GREEN	V. B. PIKE
HARRY J. KEELING	E. N. SKINNER
JOHN W. NEE	D. H. THOMPSON
C. DIETZE	R. S. TRESSEDER

CORRESPONDENTS

C. LEVINSON—Non-Ferrous Metals
O. TEEPLE—Pulp, Paper, Mining and Food
M. KALHAUGE—Petroleum Production and Pipe Lines
G. M. RIEGEL—Ferrous Metals
E. E. KULMAN—Power
RED N. REINHART—Light Metals
H. HOWARD BENNETT—Petroleum Refining
A. F. MINOR—Telephone, Telegraph and Radio
E. W. SHEPARD—Non-Metals
LEONARD C. ROWE—Transportation Industry
KENNETH W. BROWN—Fresh and Salt Water
F. J. GEGNER—Chemical Industry

BUSINESS STAFF

NORMAN E. HAMNER
Managing Editor and Advertising Manager
A. B. CAMPBELL
(Executive Secretary NACE) Business Manager

GENERAL OFFICES

1061 M & M Building, No. 1 Main St.
Houston 2, Texas

SUBSCRIPTION RATES (Postpaid)

Non-Members of NACE, 12 issues.....	\$11.00
Non-Members of NACE, Single copies, 1953 to date.....	1.00
All Issues 1945-52 Inclusive, Per Copy.....	2.00
Libraries of Educational Institutions and Public Libraries in the United States and Canada, 12 issues.....	4.00
NACE Members Receive CORROSION as a Part of Their Membership at No Extra Charge	
NACE Members, Single Copies, 1953 to date....	.50
Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds. Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1979.	

Corrosion Is Indexed Regularly by Engineering Index.

Corrosion

devoted entirely to corrosion
research and control

Published monthly as its official journal, by the National
Association of Corrosion Engineers, Inc., at Houston, Texas,
U. S. A., as a permanent record of progress in corrosion control.



Vol. 12

November, 1956

No. 11

CONTENTS

Directory of NACE Regional and Section Officers.....	Page 4, 6, 8
Officers and Directors, National Association of Corrosion Engineers.....	16

TECHNICAL SECTION

Topic of the Month—Aluminum Armor Protects Power Cables By D. M. Farnham.....	17
Laboratory Method for Corrosion Inhibitor Evaluation By G. A. Marsh and E. Schaschl.....	18
A Simple Phase Equilibrium Approach to the Problem of Oil-Ash Corrosion By W. R. Foster, M. H. Leipold and T. S. Shevlin.....	23
Magnetic Amplifier Type Recording Instrument for Electrolysis Survey By Michio Tanaka, Jiro Yamaguchi and Yoshitumi Sakurai.....	33
Potential Criteria for the Cathodic Protection of Lead Cable Sheath By K. G. Compton.....	37
Discussion: Francis W. Ringer, page 43; Sidney E. Trouard, page 44; Replies by K. G. Compton, pages 43 and 44	
Structure of Oxide Scales on Nickel-Chromium Steels By H. J. Yearian, H. E. Boren, Jr., and R. E. Warr.....	45
Discussion: Mortimer C. Bloom, page 52; Reply by H. J. Yearian, page 52	
Corrosion of Metals by Liquid Fertilizer Solutions By D. C. Vreeland and S. H. Kalin.....	53
Use of Baked Coatings in the Oil, Chemical and Processing Industries By G. J. Duesterberg.....	60
Properties, Specifications, Tests and Recommendations for Coal Tar Coatings (Part I—Hot Applied Coatings) By W. F. Fair, Jr.....	63
A Classification and Filing System for Corrosion Literature By W. L. Mathay and R. B. Hoxeng.....	72

TECHNICAL COMMITTEE ACTIVITIES

Page	Page
Gulf Offshore Structures Valued at \$150 Millions..... 77	Oil String Casing Committee Continues to Receive Reports on Corrosion Control Tests Task Groups to Probe Sweet Oil Well Corrosion..... 80
Sour Oil Well Units' Attention Focused On Vapor Space Damage, Good Reports..... 77	Acceptable Test for Sulfide Corrosion Cracking Sought..... 80
Joy Heads West Coast Asphalt Coating Unit..... 78	Coatings Application Group Organized at Los Angeles..... 82

NACE REGIONAL AND SECTIONAL NEWS

Page	Page
Coatings Scheme Keyed to Edge vs Plane Failure Ratio..... 83	Philadelphia Section Learns of Versatility, Ease of Construction of Reinforced Plastics..... 87
LaQue Talks at Los Angeles..... 83	Illustrated Lectures Favored at Philadelphia..... 87
NACE Meetings Calendar..... 83	Central Oklahoma Section..... 87
Rosemary B. Smith Joins Abstract Committee..... 84	Long Speaks at Chicago Section Ladies' Night..... 88
Tin Corrosion Is Topic of Kanawha Valley..... 84	75 From Three Societies at Brockville Session..... 88
Greater St. Louis Section Elects George T. Shutt..... 84	Record Registration Forecast at San Antonio..... 88
Los Angeles Corrosion Course Program Given National, Regional Meetings and Short Courses..... 84	Five Detroit Section Meetings Scheduled..... 88
Pipeline, Home Corrosion Discussed at San Diego..... 86	Amendments to NACE Articles and By-Laws..... 89
Tanker Corrosion Topic at San Francisco..... 86	1957 Exhibition Brochure Mailed..... 89
Culvert Corrosion Covered at Denver..... 86	Corrosion of Welded Joints Discussed by Thomas..... 89
	Where to Find NACE Technical Programs..... 89
	Boiler Water Conditions Discussed at Vancouver..... 90
	Southwestern Ohio Tours Sewage Plant..... 90

GENERAL NEWS OF CORROSION INTEREST

Page	Page
Electrochemical Society Session Attracts 900..... 91	Book Reviews..... 92
Corrosion Inhibitive Papers Discussed at St. Louis..... 91	API Smog Analyzer Works at Los Angeles..... 92
New Nickel Oxide Standard Samples Available..... 91	New Products..... 94
	Men in the News..... 98

INDEX TO CORROSION ABSTRACTS.....	99
INDEX TO ADVERTISERS.....	142

Copyright 1956 by the National Association of Corrosion Engineers. Reproduction of the contents, either as a whole or in part, is forbidden unless specific permission has been obtained from the Editor of CORROSION. Articles presented represent the opinions of their authors, and not necessarily those of the Editors of CORROSION, nor the Officers or Members of the National Association of Corrosion Engineers. Manuscripts to be considered for publication should be forwarded, together with illustrations, to the Editor of CORROSION, 1061 M & M Building, Houston 2, Texas.

Directory of NACE Technical Committees

Technical Practices Committee

C. P. Larrabee, Chairman, Applied Research Laboratory, United States Steel Corporation, Monroeville, Pennsylvania.
E. C. Greco, Vice Chairman, United Gas Corp., Box 1407, Shreveport, La.
W. H. Stewart, Vice President NACE, Sun Pipe Line Co., Sun Oil Co., Box 2831, Beaumont, Texas.
Chairmen of T-1 through T-6 also are members of this committee.

T-1 Corrosion in Oil and Gas Well Equipment

W. F. Oxford, Jr., Chairman, Sun Oil Co., Box 2831, Beaumont, Texas.
Jack L. Battle, Vice Chairman, Humble Oil & Refining Co., Box 2180, Houston, Texas.

T-1A Corrosion in Oil and Gas Well Equipment, Los Angeles Area

Howard Lorenz, Chairman, Standard Oil Company of Calif., 11-C; Camp Taft, Calif.
H. J. Klipps, Vice-Chairman, General Petroleum Corp., Box 2122, Terminal Annex, Los Angeles, Cal.

T-1B Condensate Well Corrosion

W. H. Edwards, Chairman, Superior Oil Company, 400 Oil & Gas Bldg., Houston, Texas.
D. R. Fincher, Vice Chairman, Tidewater Oil Company, 723 Sealy Street, Alvin, Texas.

T-1C Sweet Oil Well Corrosion

Joy T. Payton, Chairman, The Texas Co., Box 2332, Houston, Texas.
Rado Loncaric, Vice Chairman, Atlantic Refining Co., Box 2819, Dallas, Texas.

T-1D Sour Oil Well Corrosion

R. E. Lembcke, Chairman, Cities Service Research & Development Co., 920 East Third Street, Tulsa, Okla.
J. V. Gannon, Vice Chairman, The Texas Co., Box 1270, Midland, Texas.

T-1D-1 Fundamentals of Corrosion

J. D. Sudbury, Chairman, Production Research Division, Development and Research Dept., Continental Oil Company, Ponca City, Oklahoma.

T-1F Metallurgy

Monte Kaplan, Chairman, Atlantic Refining Co., Box 2819, Dallas, Texas.
H. M. Cooley, Vice-Chairman, Bethlehem Steel Co., Box 2171, Tulsa, Okla.

T-1G Sulfide Stress Corrosion Cracking

Monte Kaplan, Chairman, The Atlantic Refining Co., Box 2819, Dallas, Texas.
J. J. B. Rutherford, Vice-Chairman, Tubular Products Div., The Babcock and Wilcox Co., Beaver Falls, Pa.

T-1H Oil String Casing Corrosion

W. C. Koger, Chairman, Cities Service Oil Co., Cities Service Building, Bartlesville, Oklahoma.

T-1H1 Oil String Casing Corrosion, West Texas, New Mexico Area

R. L. Elkins, Chairman, Shell Oil Company, Box 3832, Odessa, Texas.

T-1H-2 Oil String Casing Corrosion, West Kansas Area

R. L. Conboy, Chairman, Gulf Oil Corp., Box 225, Great Bend, Kan.

T-1H-3 Oil String Casing Corrosion, East Texas Area

M. J. Olive, Chairman, Arkansas Fuel Oil Corp., General Engineering Department, Box 1117, Shreveport, La.

T-1H-4 Oil String Casing Corrosion, California Area

F. W. Schremp, Chairman, California Research Corp., Box 446, LaHabra, Cal.

T-1J Oil Field Structural Plastics

B. W. Bradley, Chairman, Shell Oil Co., 1175 University Ave., Berkeley, California.
W. B. Sanford, Vice-Chairman, Minnesota Mining & Mfg. Co., 900 Fauquier Ave., St. Paul, Minn.

T-1K Inhibitors for Oil and Gas Wells

A. H. Roebuck, Chairman, Production Research Div., Continental Oil Co., Ponca City, Okla.
E. J. Simmons, Vice-Chairman, Sun Oil Co., Box 2880, Dallas, Texas.

T-1M Corrosion of Oil and Gas Well Producing Equipment in Offshore Installations

D. F. Dial, Jr., Chairman, Pure Oil Co., Box 239, Houston, Texas.
F. E. Blount, Vice Chairman, Magnolia Petroleum Co., Box 900, Dallas, Texas.

T-2 Pipe Line Corrosion

W. H. Stewart, Chairman, Sun Pipe Line Company, Sun Oil Company, Box 2831, Beaumont, Texas.
L. P. Sudrabin, Vice Chairman, Electro Rust-Proofing Corp., Box 178, Newark, New Jersey.

T-2A Galvanic Anodes

H. W. Wahlquist, Chairman, Ebasco Services, Inc., 2 Rector St., New York, N. Y.
J. A. Holloway, Vice-Chairman, Box 727, Edna, Texas.

T-2B Anodes for Impressed Currents

T. J. Maitland, Chairman, American Telephone & Telegraph Co., 32 Avenue of the Americas, New York 13, New York.

T-2C Minimum current requirements

R. M. Walnwright, Chairman, Good-All Electric Mfg. Co., Ogallala, Nebraska.
Paul T. Miller, Vice Chairman, The Texas Pipe Line Co., Box 647, Alameda, Texas.

T-2D Standardization of Procedures for Measuring Pipe Coating Leakage Conductance

Marshall E. Parker, Chairman, Cormit Engineering Co., 717A M&M Building, Houston, Texas.

T-2E Internal Corrosion of Product Pipe Lines and Tanks

Ivy M. Parker, Chairman, Plantation Pipe Line Co., Box 1743, Atlanta, Georgia.
A. W. Jasek, Vice Chairman, Humble Pipe Line Co., Drawer 2220, Houston, Texas.

T-2F Internal Corrosion of Crude Oil Pipe Lines and Tanks

J. C. Watts, Jr., Chairman, Internal Pipeline Maint. Company, Box 186, Odessa, Texas.

T-2G Coal Tar Coatings for Underground Use

T. F. P. Kelly, Chairman, Mavor-Kelly Co., 660 M & M Building, Houston 2, Texas.
W. F. Fair, Jr., Vice Chairman, Koppers Co., Inc., Tar Products Div., Tech. Serv., 15 Plum St., Verona, Pa.

T-2H Asphalt Type Pipe Coatings

Austin S. Joy, Chairman, Brumley-Donaldson Co., 3050 East Slauson Avenue, Huntington Park, Cal.
P. E. Reynolds, Vice Chairman, Pacific Gas & Electric Co., 245 Market St., San Francisco, California.

T-2J Wrappers for Underground Pipe Line Coating

Clark A. Bailey, Chairman, Johns-Manville Sales Corp., 22 East 40th St., New York 16, N. Y.
O. W. Wade, Vice Chairman, Transcontinental Gas Pipe Line Corp., Box 296, Houston, Texas.

T-2K Prefabricated Plastic Film for Pipe Line Coating

F. E. Costanzo, Chairman, 253 Ryan Drive, Pittsburgh 20, Pa.
J. J. Wise, Vice Chairman, Arkansas-Louisiana Gas Company, Box 1734, Shreveport, La.

T-3 GENERAL

F. W. Fink, Chairman, Battelle Memorial Institute, 505 King Ave., Columbus, Ohio.
A. H. Roebuck, Vice Chairman, Production Research Division, Continental Oil Company, Ponca City, Oklahoma.

T-3A Corrosion Inhibitors

J. L. Wasco, Chairman, The Dow Chemical Co., Bldg. 438, Midland, Michigan.
S. K. Coburn, Vice Chairman, Association of American Railroads, 3140 S. Federal St., Chicago, Illinois.

T-3A-1 General Theory of the Action of Corrosion Inhibitors

W. W. Sweet, Chairman, Research & Development Dept., Colgate Palmolive Co., 105 Hudson St. Jersey City, N. J.

T-3A-2 Methods of Testing & Screening Corrosion Inhibitors

(Chairman to be Selected)

T-3A-3 Materials Available for and Application of Corrosion Inhibitors

Lyle Timm, Chairman, Sharples Chemicals, Inc., Box 151, Wyandotte, Mich.

T-3B Corrosion Products

A. H. Roebuck, Chairman, Production Research Division, Continental Oil Company, Ponca City, Okla.
D. A. Vaughan, Vice Chairman, Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio.

T-3C Annual Losses Due to Corrosion

F. N. Alquist, Chairman, The Dow Chemical Co., Bldg. 438, Midland, Michigan.
S. K. Coburn, Vice Chairman, Association of American Railroads, 3140 S. Federal St., Chicago, Ill.

T-3D Instruments for Measuring Corrosion

H. N. Hayward, Chairman, Engineering Experiment Station, University of Illinois, Urbana, Illinois.
F. W. Ringer, Vice Chairman, 7 Hampden Ave., Narberth, Pa.

T-3D-1 Electrical Holiday Inspection of Coatings

Lyle R. Sheppard, Chairman, 6522 Mercer St., Houston, Texas.

T-3E Railroads

L. J. Nicholas, Chairman, The Pullman Company, 701 East 114th Street, Chicago 28, Ill.
G. M. Magee, Vice Chairman, Assoc. American Railroads, 3140 South Federal Street, Chicago, Ill.

T-3E-1 Corrosion of Railroad Tank Cars

J. R. Spraul, Chairman, General American Transportation Corp., 150 West 151st Street, East Chicago, Ind.
C. M. Jekot, Vice Chairman, DeSoto Paint & Varnish Co., P. O. Box 186, Garland, Texas.

L. R. Honnaker, Vice Chairman, Engineering Materials Group, Eng. Dept., E. I. du Pont de Nemours & Co., Inc., 13W10 Louviers Bldg., Wilmington, Del.

T-3E-2 Corrosion in Railroad Hopper Cars

C. L. Crockett, Chairman, Norfolk and Western Railway, Mott Power Dept., Roanoke, Va.

T-3F Corrosion by High Purity Water

D. J. DePaul, Chairman, Westinghouse Electric Corp., Atomic Power Division, Box 1468, Pittsburgh 30, Pa.
J. F. Eckel, Vice Chairman, Dept. of Metallurgical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

(Continued on Page 6)

TODD gets ONE-COAT VINYL BUILD with SPEE-FLO hot spray

Todd Shipyard Corporation's General Manager James Goodrich wanted to cut down the 4-5 coats required for a specified mill-thickness of cold-sprayed protective vinyl finish. He found the answer—and improved quality at substantially lower cost—with Spee-Flo hot spray equipment. Now, equivalent thickness is obtained with a one-coat application at great savings in time and material.



Users of the hot spray process for vinyl coatings report up to 300% longer film life, with average material savings of 25%, due largely to reduced overspray. With hot spray, there are no runs and sags; finish is smoother with less orange peel; build, hold-out, and coverage are improved.

VISIT US AT THE
PLANT MAINTENANCE
SHOW
JANUARY 28-31
CLEVELAND

WHAT TO LOOK FOR IN HOT SPRAY EQUIPMENT

1. **Simplicity**—simple as an electric light. Turn it on in the morning . . . ready to spray in 5 minutes. Turn it off at night . . . patented, coil-less construction eliminates daily cleanout or attention.
2. **Efficiency**—full heating range . . . 90 to 180 degrees F. Easy, accurate control . . . maintains "factory fresh" efficiency . . . no coils to clog, no pump gears to wear.
3. **Proof**—watch it work! There are 26 trained sales engineers, plus local distributors everywhere, who maintain stocks of Spee-Flo equipment. Ask for a demonstration.

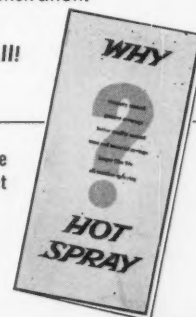
**Spee-Flo Equipment Has 'Em All!
Compare Before YOU Buy.**



Get all the facts, including case history data, in the free booklet "Why Hot Spray?"

SPEE-FLO

HOT SPRAY HEATERS
Dept. C-29, 720 Polk, Houston, Tex.



Directory of NACE Technical Committees

(Continued From Page 4)

T-3G Cathodic Protection

T. P. May, Chairman, The International Nickel Co., Inc., 67 Wall St., New York, N. Y.

T-3G-1 Cathodic Protection of Hull Bottoms of Ships

L. P. Sudrabin, Chairman, Electro Rust-Proofing Corp., Box 178, Newark, New Jersey.

T-3G-2 Cathodic Protection of Heat Exchangers

R. B. Teel, Chairman, The International Nickel Co., Inc., Box 262, Wrightsville Beach, N. C.

T-3G-3 Cathodic Protection of Process Equipment

A. A. Brouwer, Chairman, The Dow Chemical Co., Midland, Michigan.

T-3H Tanker Corrosion

W. S. Quimby, Chairman; Res. & Tech. Dept., The Texas Company, Box 509, Beacon, New York.

T-4 UTILITIES

Irwin C. Dietze, Chairman, Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles, Calif.

T-4A Effects of Electrical Grounding on Corrosion

T. R. Stilley, Chairman; Good-All Electric Mfg. Co., Good-All Bldg., Ogallala, Neb.

T-4B Corrosion of Cable Sheaths

Irwin C. Dietze, Chairman, Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles, California.
D. T. Rosselle, Vice Chairman, Southern Bell Telephone & Telegraph Co., 1424 Hurt Building, Atlanta, Ga.

T-4B-1 Lead and Other Metallic Sheaths

T. J. Maitland, Chairman, American Telephone & Telegraph Co., 32 Avenue of the Americas, New York 13, New York.

T-4B-2 Cathodic Protection

R. M. Lawall, Chairman, Amer. Tel. & Tel. Co., 1538 Union Commerce Bldg., Cleveland 14, Ohio.
J. J. Pokorny, Vice Chairman, Cleveland Elec. Illuminating Co., 75 Public Sq., Cleveland 1, Ohio.

T-4B-3 Tests and Surveys

D. R. Werner, Chairman, American Telephone & Telegraph Co., 324 East 11th Street, Room 1701, Kansas City, Mo.

T-4B-4 Protection of Pipe Type Cables

H. W. Dieck, Chairman, Long Island Lighting Company, 175 Old Country Road, Hicksville, New York.
J. B. Prime, Jr., Vice Chairman, Florida Power & Light Co., Box 3100, Miami, Florida.

T-4B-5 Non-Metallic Sheaths and Coatings

G. H. Hunt, Chairman, Simplex Wire & Cable Co., 79 Sidney St., Cambridge 39, Massachusetts.

T-4B-6 Stray Current Electrolysis

J. Svetlik, Chairman, Northern Indiana Public Service Co., 5265 Hohman Ave., Hammond, Indiana.
G. H. Cantwell, Vice Chairman, Indiana Bell Telephone Co., 240 N. Meridian St., Indianapolis, Indiana.

T-4D Corrosion by Deicing Salts

D. W. Kaufmann, Chairman, International Salt Co., Inc., 638 Marine Trust Bldg., Buffalo, New York.
W. H. Bruckner, Vice Chairman, University of Illinois, Urbana, Illinois.

T-4E Corrosion by Domestic Waters

T. E. Larson, Chairman, Illinois State Water Survey, Box 232, Urbana, Illinois.

T-4F Materials Selection for Corrosion Mitigation in the Utility Industry

F. E. Kulman, Temporary Chairman, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York, N. Y.

T-4F-1 Materials Selection in the Water Industry

Daniel Cushing, Chairman, 148 State St., Boston, Massachusetts.

T-4F-2 Materials Selection in the Electric Industry

L. P. Shaefer, Chairman, The Hinchman Corp., Francis Palms Bldg., Detroit, Mich.

T-5 Corrosion Problems in the Process Industries

Wm. G. Ashbaugh, Chairman, Carbide & Carbon Chemicals Co., Texas City, Texas.
R. I. Zimmerer, Vice Chairman, Petro-Tex Chemical Corp., Box 2584, Houston 1, Texas.

T-5A Chemical Manufacturing Industry

R. I. Zimmerer, Vice Chairman, Petro-Tex Chemical Corp., Box 2584, Houston 1, Texas.
A. C. Hamstead, Vice Chairman, Carbide & Carbon Chemicals Co., South Charleston, West Virginia.

T-5A-1 Sulfuric Acid

C. L. Bulow, Chairman, Bridgeport Brass Co., 30 Grand St., Bridgeport, Conn.
W. A. Luce, Vice Chairman, The Duriron Co., Box 1019, Dayton, Ohio.

T-5A-3 Acetic Acid

H. O. Teeple, Chairman, The International Nickel Co., Inc., 67 Wall St., New York, New York.

T-5A-4 Chlorine

Wayne Inbody, Chairman, Diamond Alkali Co., Box 348, Painesville, Ohio.

T-5A-5 Nitric Acid

J. L. English, Chairman, Oak Ridge National Laboratory, Box P, Oak Ridge, Tenn.
W. H. Burton, Vice Chairman, General Chemical Division, Allied Chemical & Dye Corp., Camden, New Jersey.

T-5A-6 HF Corrosion

T. L. Hoffman, Chairman, Phillips Petroleum Co., Atomic Energy Div., Box 1259, Idaho Falls, Idaho.

T-5B High Temperature Corrosion

E. N. Skinner, Chairman; The International Nickel Co., Inc., 67 Wall St., New York, N. Y.
J. L. McPherson, Vice-Chairman, 427 Murdock Ave., R.F.D. 2, Library, Pa.

T-5B-2 Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry

M. E. Holmberg, Chairman, 4101 San Jacinto St., Houston, Texas.

T-5B-3 Oil Ash Corrosion

R. T. Foley, Chairman, General Electric Co., Schenectady, New York.

T-5B-5 Corrosion by Molten Salts and Metals

W. D. Manly, Chairman, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

T-5C Corrosion by Cooling Waters

T-5C-1 Corrosion by Cooling Waters (South Central Region)
C. P. Dillon, Chairman; Carlide & Carbon Chemicals Co., Texas City, Texas.

M. Brooke, Vice Chairman; Phillips Petroleum Co., Sweeny Refinery, Sweeny, Texas.
W. W. Wheeler, Secretary; Rohm & Haas, Box 672, Pasadena, Texas.

T-5D Plastic Materials of Construction

S. W. McIlrath, Chairman, 151 East 214th St., Euclid, Ohio.
R. E. Gackenbach, Vice-Chairman, American Cyanamid Co., Organic Chemical Div., Bound Brook, N. J.
J. S. McBride, Secretary; Owens-Corning Fiberglass Corp., Ashton, Rhode Island.

T-5D-1 Questionnaires

S. W. McIlrath, Chairman, 151 E. 214th Street, Euclid 23, Ohio.

T-5D-2 Inorganic Acids

R. L. Hughes, Chairman, Spencer Chemical Co., 1231 Woodsworth Rd., Kansas City, Missouri.
J. F. Malone, Secretary, B. F. Goodrich Chemical Co., 2060 East Ninth Street, Cleveland 15, Ohio.

T-5D-3 Inorganic Alkalies

Peter Kimen, Chairman, Champion Paper & Fibre Co., Box 872, Pasadena, Texas.
L. B. Connolly, Secretary, Eastman Chemical Products Company, 704 Texas National Bank Building, Houston 2, Texas.

T-5D-4 Gases

Beaumont Thomas, Chairman, Stebbins Eng. & Mfg. Co., Eastern Blvd., Watertown, New York.
J. L. Forse, Vice Chairman, Dow Chemical Company, Plastics Technical Service, Midland, Michigan.
William Eakins, Secretary, Chemical Corporation, Plastics Division, West Warren, Massachusetts.

T-5D-5 Water and Salt Solutions

Paul Elliott, Chairman, Naugatuck Chemical Company, Kralastic Development, Naugatuck, Conn.

T-5D-6 Organic Chemicals

B. B. Pusey, Vice-Chairman, Bakelite Co., Div. of U.C.C., Bound Brook, New Jersey.
Wade Wolfe, Jr., Secretary, 71 Ermann Drive, Buffalo 17, New York.

T-5D-7 Engineering Design

O. H. Fenner, Chairman, Monsanto Chemical Company, 1700 South Second Street, St. Louis 4, Missouri.
K. A. Phillips, Vice-Chairman, American Zinc, Lead & Smelting Co., P. O. Box 495, East St. Louis, Illinois.
W. B. Meyer, Secretary, St. Louis Metallizing Co., 625 South Sarah, St. Louis 10, Missouri.

T-5D-8 Methods and Criteria for Evaluating Plastics in Chemical Environment

R. F. Clarkson, Chairman, Olin Mathieson Chemical Corp., Mathieson Building, Baltimore, Md.
R. Lembecke, Secretary, Cities Service Res. & Dev. Co., 929 East Third, Tulsa 3, Oklahoma.

T-5E Stress Corrosion Cracking of Austenitic Stainless Steel

L. Miller Rogers, Chairman, Union Carbide & Carbon Chemical Co., Box 471, Texas City, Texas.

T-6 Protective Coatings

L. L. Whiteneck, Chairman; Plicoflex, Inc., 1566 E. Shawson Avenue, Los Angeles 11, Cal.
L. S. Van Delinder, Vice Chairman, Carbide & Carbon Chemicals Co., South Charleston, West Va.

T-6A Organic Coatings and Linings for Resistance to Chemical Corrosion

R. McFarland, Jr., Chairman, Hills-McCanna Co., 3025 N. W. Ave., Chicago 18, Illinois.
C. G. Munger, Vice-Chairman, Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
L. A. Ferris, Secretary, E. I. DuPont de Nemours & Co., Inc., Polychemicals Dept., Wilmington, Delaware.

T-6A-1 Heavy Linings

H. C. Klein, Chairman, B. F. Goodrich Co., Cuyahoga Falls, Ohio.

T-6-2 Vinyl Coatings

K. Tator, Chairman, 2020 Mac-tour Street, Coraopolis, Pa.

(Continued on Page 8)

Chairman,
fig. Co.,
ertown,
Chairman,
npany,
Service,
Secretary,
n, Fla.,
Warren,

Salt

Nauga-
npany,
pment,

Chemicals

Chairman,
U.C.C.,
ersey,
etary, 73
falo 17,

Design

n, Mon-
npany,
reet, St.

Chairman,
& Smelt-
95, East

ary, St.
Co., 625
ouis 19,

and Cri-
ng Plas-
Environ-

n, Olin
Corp.,
g, Balti-

y, Cities
Co., 929
3, Okla-

n
stainless

Chairman,
Carbon
71, Texas

Chairman;
E. Siau-
angeles 11,

ce Chair-
on Chem-
harleston,

ings and
resistance
corrosion

Chairman,
3025 N.
Illinois
Chairman,
09 Fire-
ate, Calif.
ry, E. I.
& Co.,
Dept.,
re.

ings
an, B. F.
oga Falls,

ings
020 Mon-
ilis, Pa.
ge 8)



transcontinental pipelines are among the many places where Cathodic Protection and Anaconda Type CP Cable are used to check corrosion.

Cable that helps make the pipeline a good neighbor

To make cathodic protection systems more economical and effective — to help pipeline and oil companies check costly corrosion, stop leaks, make pipelines good neighbors — Anaconda offers a special Type CP Cable that lasts far longer on the job than ordinary cable.

High-grade polyethylene insulation and tough Densheath* (PVC) jacket offer high resistance to electroendosmosis†, as well as high resistance to oil, moisture, and most acids, alkalis and chemicals found in corrosive areas. And rugged Densheath withstands toughest abrasion, moisture,

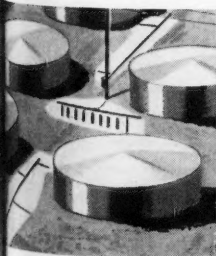
sunlight and weathering.

For special applications, a one-layer insulation and jacket construction of polyethylene is available.

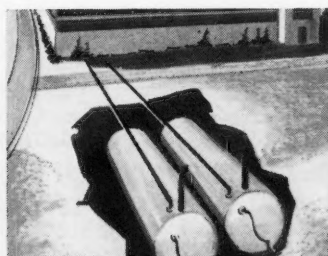
To order, or for more information—call the Man from Anaconda. Or write: Anaconda Wire & Cable Company, 25 Broadway, New York 4, N. Y.

*Reg. U.S. Pat. Office †Cable failure on direct current in wet locations 56357 Rev.

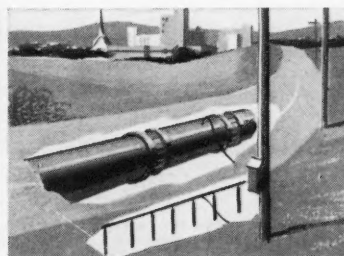
WHERE ANACONDA TYPE CP CABLE AND CATHODIC PROTECTION CUT CORROSION COSTS



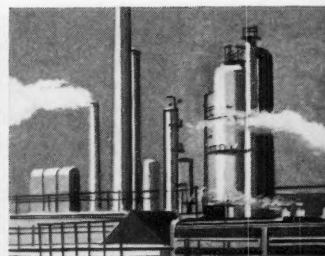
Tank farms



Underground storage tanks



Pipelines



Oil refineries

ASK THE MAN FROM **ANACONDA**
FOR CATHODIC PROTECTION CABLE

added protection with **HOT-DIP** Galvanizing!



ARMOR-PLATE structural steel, wire, pipe, fasteners and other metal items against rust with a tough zinc coating from the vats of the Nowery J. Smith Company. For the best in galvanizing service whether your job is routine or really rare, call the Nowery J. Smith Co. in Houston.

Nowery J. Smith
COMPANY

Hempstead Hwy. at Eureka Underpass

one of the **SMITH**



Directory of Technical Committees

(Continued from Page 6)

• T-6A-3 Vinylidene Chloride Polymers

R. L. Brown, Chairman, The Dow Chemical Co., Midland, Mich.

• T-6A-4 Phenolics

Forest Baskett, Chairman; Sheet Metal Engineers, Inc., Box 9094, Houston 11, Texas.

• T-6A-5 Polyethylene

L. S. Van Delinder, Chairman, Carbide & Carbon Chemicals Co., South Charleston, West Va.

• T-6A-6 Rubber and Elastomers

H. C. Klein, Chairman, B. F. Goodrich Co., Cuyahoga Falls, Ohio.

• T-6A-7 Silicones

R. McFarland, Jr., Chairman, Hills-McCanna Co., 3025 N. Western Ave., Chicago, Ill.

• T-6A-8 Methacrylates

Forest Baskett, Chairman; Sheet Metal Engineers, Inc., Box 9094, Houston 11, Texas.

• T-6A-9 Furanos

Forest Baskett, Chairman; Sheet Metal Engineers, Inc., Box 9094, Houston 11, Texas.

• T-6A-10 Polyesters

D. D. Cone, Chairman; Insul-Mastic Corp. of America, 7750 W. 61st Place, Summit, Ill.

• T-6A-11 Epoxys

C. G. Munger, Chairman, Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal.

• T-6A-12 Fluorocarbons

L. A. Ferris, Chairman, E. I. Du Pont de Nemours & Co., Inc., Wilmington, Delaware.

• T-6A-13 Bituminous

C. U. Pittman, Chairman; Koppers Co., Inc., Tar Products Div., Tech. Dept., Box 128, Verona, Pa.

• T-6A-14 Organic-Brick Covered

R. W. Hall, Chairman; Stebbins Engr. & Mfg. Co., 363 Eastern Blvd., Watertown, N. Y.

T-6B Protective Coatings for Resistance to Atmospheric Corrosion

Howard C. Dick, Chairman, Products Research Service, Inc., Box 6116, New Orleans, La.; R. S. Freeman, Vice-Chairman; Cities Service Refining Corp., Box 1562, Lake Charles, La.

T-6C Protective Coatings for Resistance to Marine Corrosion

Raymond P. Devoe, Chairman, The Glidden Co., Room 1310, 52 Vanderbilt Avenue, New York 17, New York; R. F. Daw, Vice-Chairman, The Texas Co., 135 East 42nd St., New York 17, New York.

T-6D Industrial Maintenance Painting

J. C. Coffin, Chairman, The Dow Chemical Company, Bldg. 298, Midland, Mich.

T-6E Protective Coatings in Petroleum Production

F. T. Rice, Chairman, The Pure Oil Co., 35 E. Wacker Drive, Chicago, Ill.; D. F. Dial, Jr., Vice-Chairman; The Pure Oil Co., Box 239, Houston, Texas.

T-6F Protective Coatings Equipment, Methods and Costs

W. P. Cathcart, Chairman, Tank Lining Corporation, 246 Washington Road, Pittsburgh, Pennsylvania.

T-6G Surface Preparation for Organic Coatings

S. E. Jack, Chairman, Aluminium Laboratories, Ltd., Box 84, Kingston, Ontario, Canada; S. C. Frye, Vice Chairman, Research Dept., Bethlehem Steel Co., Bethlehem, Pa.

T-6H Glass Linings and Vitreous Enamels

G. H. McIntyre, Chairman, Ferro-Enamel Corporation, 4150 East 56th Street, Cleveland, Ohio.

T-6J Protective Coating Application Problems

Ivan Sullivan, Chairman, Spence & Sullivan, Inc., 344 East Carson St., Torrance, Cal.; F. M. McConnell, Vice Chairman, Service Coatings Corp., 217 North Lagoon, Wilmington, Cal.

W. M. Jakway, Secretary, Bechtel Corp., Box 58424, Los Angeles, Cal.

T-6K Corrosion Resistant Construction With Masonry and Allied Materials

L. R. Honnaker, Chairman; E. I. DuPont de Nemours Company, Inc., Eng. Dept., 13W15 Louvers Bldg., Wilmington, Del.; George P. Gabriel, Vice Chairman, Atlas Mineral Products Company, Mertztown, Pa.

T-6R Protective Coatings Research

Joseph Bigos, Chairman, Steel Structures Painting Council, Mellon Inst., 4400 Fifth Ave., Pittsburgh 13, Pa.; J. H. Cogshall, Vice-Chairman, Pennsylvania Salt Mfg. Co., 3 Penn. Center Plaza, Philadelphia, Pa.

T-7 Corrosion Coordinating Committee

J. M. Fouts, Chairman, New York Telephone Company, 63 E. Delavan Avenue, Buffalo, New York; J. A. Erickson, Jr., Vice Chairman; The Peoples Natural Gas Company, Two Gateway Center, Pittsburgh 22, Pa.

T-7A Northeast Region Corrosion Coordinating Committee

C. A. Erickson, Jr., Chairman, The Peoples Natural Gas Company, 140 Stanwix Street, Pittsburgh, Pa.; L. Andrew Kellogg, Vice-Chairman; Niagara Mohawk Power Corp., 300 Erie Blvd., West, Syracuse, N. Y.

T-7B North Central Region Corrosion Coordinating Committee

(Officers not yet selected)

T-7C Southeast Region Corrosion Coordinating Committee

Ernest W. Seay, Jr., Chairman, Chesapeake & Potomac Tel. Co. of Va., 120 W. Bute St., Norfolk, Va.

T-7D South Central Region Corrosion Coordinating Committee

(Officers not yet selected)

T-7E Western Region Corrosion Coordinating Committee

Irwin C. Dietze, Chairman, Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles, Calif.; J. S. Dorsey, Vice Chairman, Southern California Gas Co., 3249 Terminal Annex, Los Angeles, Calif.

T-7F Canadian Region Corrosion Coordinating Committee

(Officers not yet selected)

ARTICLES SCHEDULED FOR PUBLICATION SOON:

Naphthenic Acid Corrosion—An Old Enemy of the Petroleum Industry by W. A. Derungs

Coal Tar Coatings. Part 2 of Paper 1: Properties, Specifications, Tests and Recommendations by W. F. Fair, Jr.

Laboratory Method for Corrosion Inhibitor Evaluation by G. A. Marsh and E. Schaschl

Design and Engineering of Plastic Materials of Construction by Otto H. Fenner and R. P. Whittier

Evaluation of Cooling Tower Corrosion Inhibitors by Charles B. Friedman and W. L. Denman

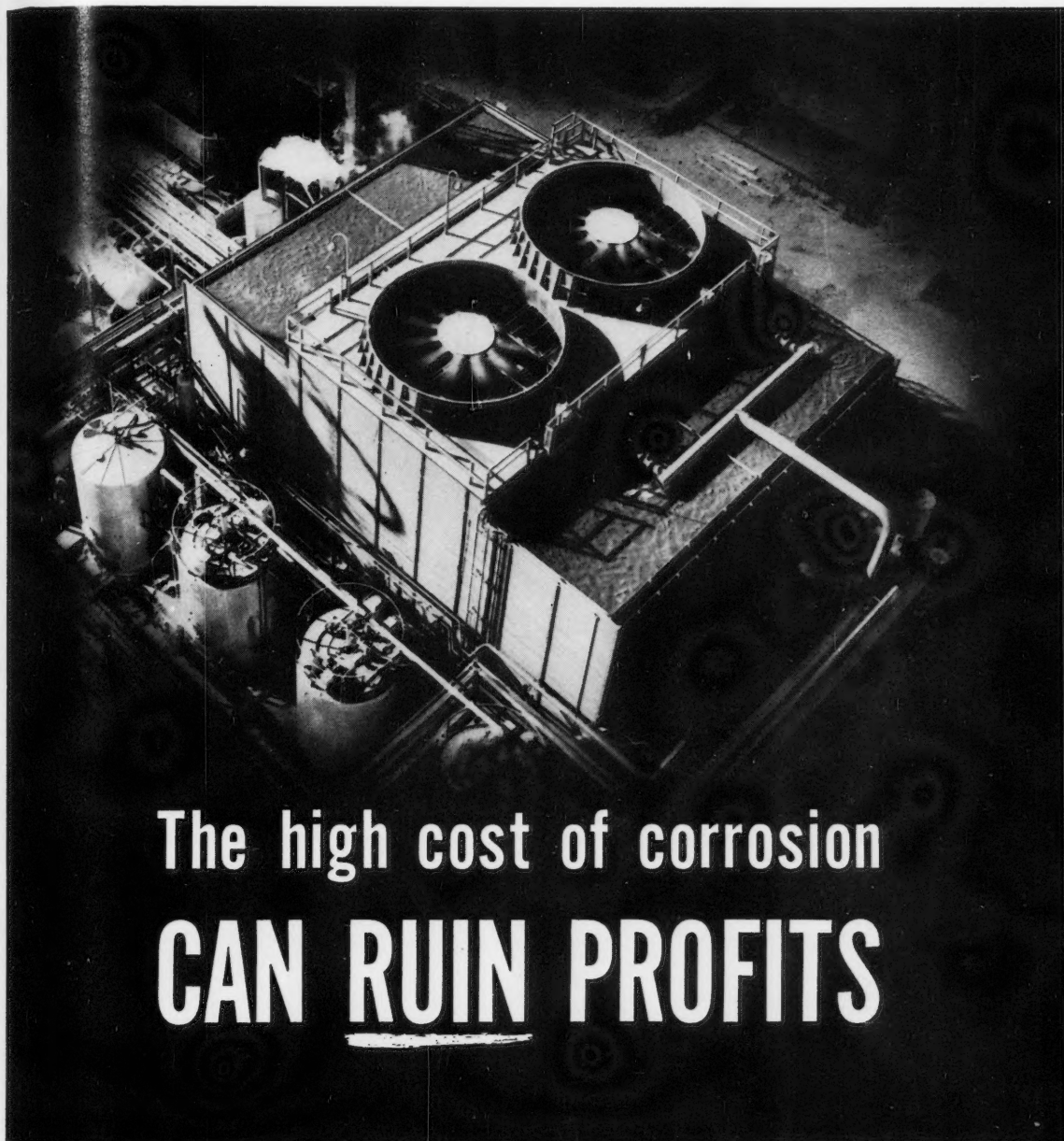
Casing Corrosion in the Petroleum Industry by Jack L. Battle

Stress Corrosion Cracking of Metal in Hydrofluoric Acid by H. R. Copson and C. F. Cheng

Problems of Corrosion in Large Steam Generating Stations by T. J. Finnegan

Sprayed Metal as a Base for Paints by H. S. Ingham

An Engineering Approach to the Estimating of Maintenance Painting by R. F. Williams and J. H. Cogshall



The high cost of corrosion **CAN RUIN PROFITS**

Photograph Courtesy Marley Co., Inc.

There is no denying that corrosion and other water damage in cooling and process water systems can cut a big slice out of profits. Pipes, heat exchange equipment and cooling towers may suffer costly damage, and the time lost during outages piles up excess production costs.

Calgon Engineering Service has developed specific answers to water damage problems. Protection for the entire system, from cooling towers on through, is set up. Iron and steel surfaces can be given fast and more complete protection with Calgon* composition TG, remarkable for its accelerated film forming ability. Copper or copper alloy corrosion can be inhibited with Coraid, which is effective at both high and low pH values.

Write or phone for information on how Calgon Engineering Service can help you.

calgon, inc.

A SUBSIDIARY OF
HAGAN CORPORATION
HAGAN BUILDING
PITTSBURGH 30, PA.



*Calgon is the Registered Trade Mark of Calgon, Inc., for its sodium phosphate glass (sodium hexametaphosphate) products.

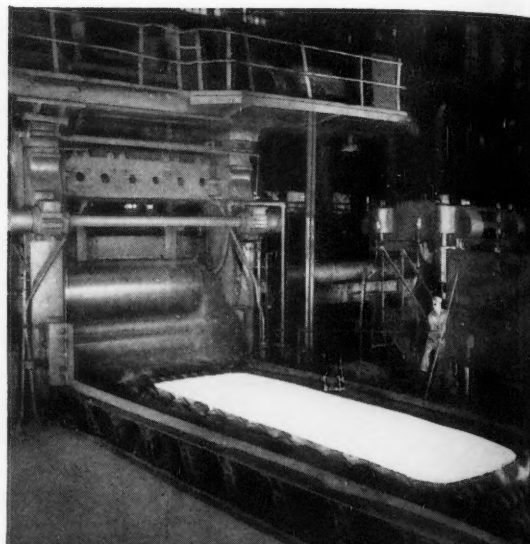
step by step...

CLAYMONT BUILDS QUALITY INTO ITS

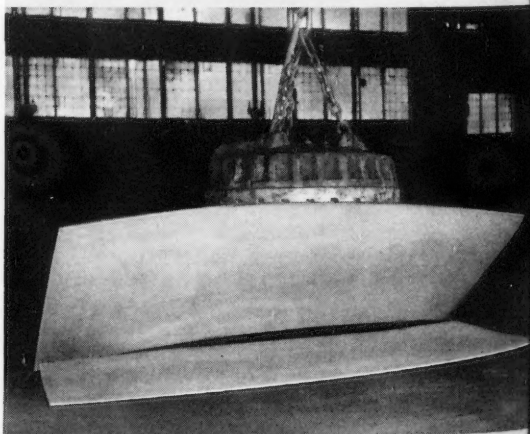
■ Dependability and economy are two characteristics of *every* stainless-clad product that bears the Claymont name. These characteristics are assured by Claymont's careful quality control system—a system that step-by-step builds superior quality into *every* Claymont Product.



1. Skilled metallurgists begin testing Claymont steel long before it leaves the open hearths to make sure that it is never "off-heat". This supervision never ceases until the stainless-clad product is finally shipped.

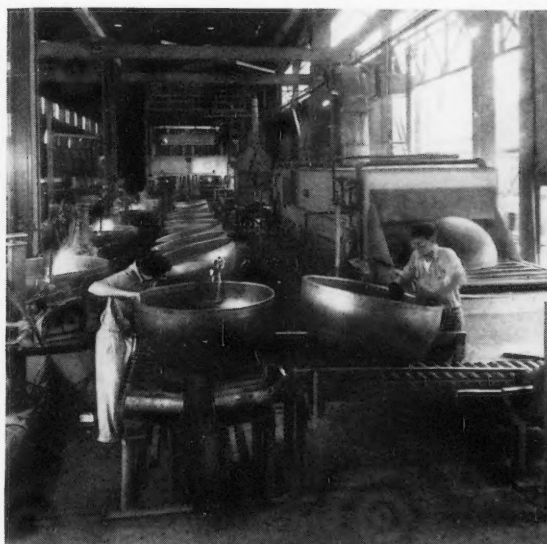
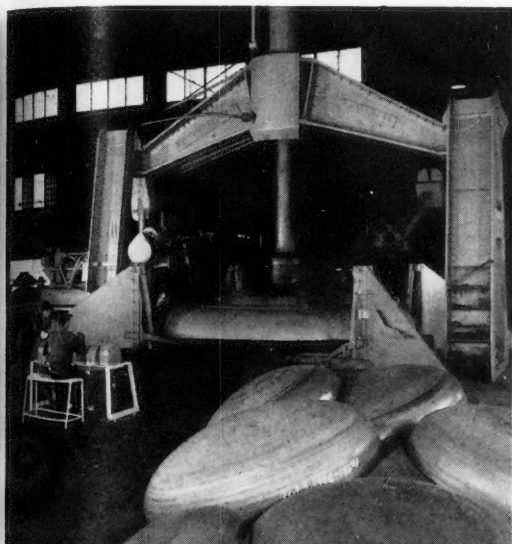


2. First step in making stainless-clad plates is to assemble a "sandwich"—composed of two stainless steel plates between two carbon or alloy steel backing plates. Next, the sandwich is slowly heated to 2250° F and rolled as a single unit, permanently bonding each stainless plate to its backing plate. A special compound between the stainless plates keeps them from fusing together.



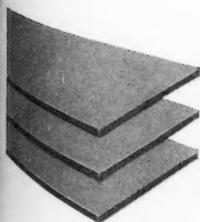
3. After a controlled cooling period, the assembly is sheared or burned, then separated producing two stainless-clad plates. They are then carefully heat treated, resheared to exact size, sandblasted, and inspected.

TO ITS STAINLESS-CLAD PRODUCTS

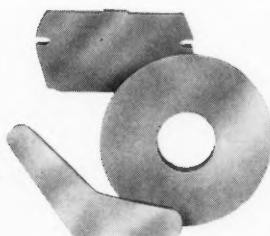


4. Claymont Stainless-Clad Steel Heads are spun or pressed in sizes up to 19 feet and in a wide variety of shapes—flanged and dished, elliptical, conical, hemispherical, etc. Shown here are two units in Claymont's extensive head-forming facilities—a large spinning machine and a new, automatic 3000-ton press.

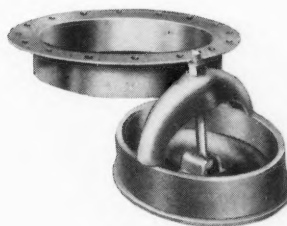
OTHER CLAYMONT PRODUCTS



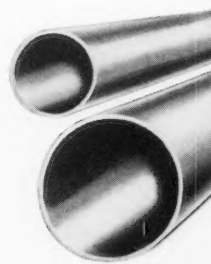
Steel Plates
Alloy • Nickel Plated •
High Strength Low Alloy



Fabricated
Steel Parts



Manhole Fittings
and Covers



Large Diameter
Welded Steel Pipe



Claymont Steel Products

Products of Wickwire Spencer Steel Division • The Colorado Fuel and Iron Corporation

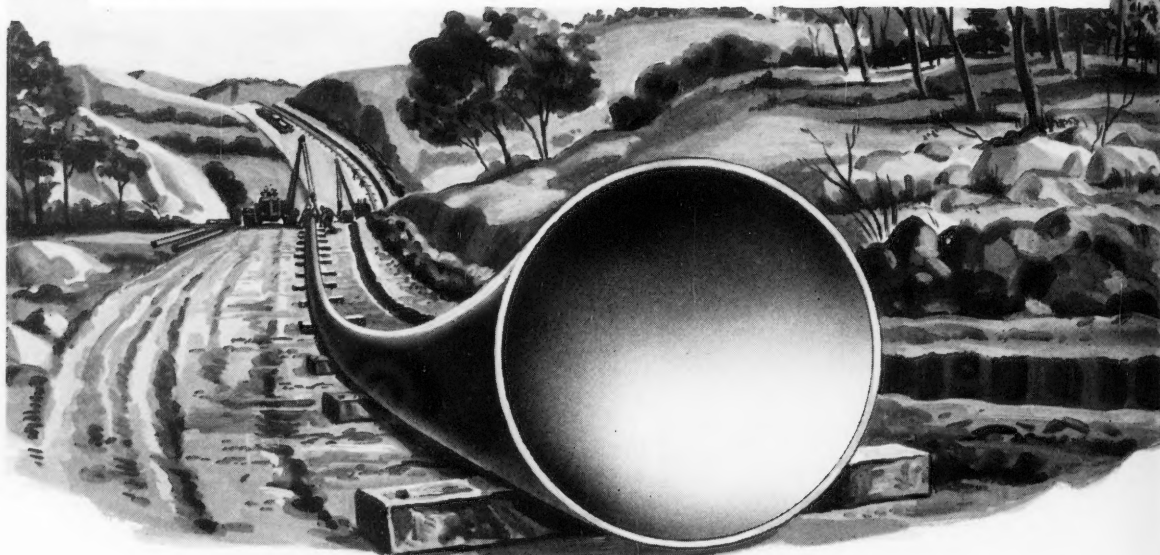
Albuquerque • Amarillo • Atlanta • Billings • Boise • Boston • Buffalo • Butte • Casper • Chicago • Denver • Detroit • El Paso • Ft. Worth
Houston • Lincoln • Los Angeles • New Orleans • New York • Oakland • Odessa • Oklahoma City • Philadelphia • Phoenix • Portland (Ore.)
Pueblo • Salt Lake City • San Francisco • Seattle • Spokane • Tulsa • Wichita

CF&I OFFICES IN CANADA: Toronto • Montreal

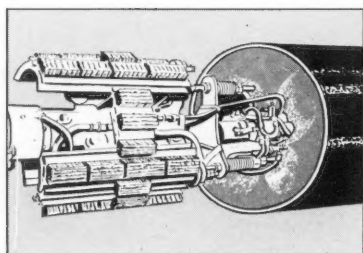
CANADIAN REPRESENTATIVES AT: Calgary • Edmonton • Vancouver • Winnipeg

4440

REPEAT PERFORMANCE



Copon internal pipe coating selected again by major gas transmission company



Thirty and thirty-six inch pipe being automatically spray-painted at mill following unique metal cleaning process.

► Proof of COPON'S effectiveness in solving internal pipe coating problems lies in its growing acceptance by major gas transmission companies. This year it's being used again by one leading firm for new 30" and 36" pipeline construction in addition to many other projects.

COPON internal pipe coatings offer *even more* than outstanding protection against corrosion losses. They *pay off* in protection during storage, lowered maintenance expense and greatly reduced pigging costs. And COPON coatings make possible delivery of cleaner, rust-free gas products.

Scientifically developed systems are available for coating dehydrated gas lines, crude and petroleum product lines, salt water lines, fresh water lines, and oil well tubing and casing. Write your nearest COPON manufacturer today. He will be happy to show you how COPON can be efficiently applied to new pipe, used pipe or pipe-in-ground.

Get complete information about COPON today. ↘

MAIL COUPON TODAY

C-11

Please send me information about COPON Internal Pipe Coatings.

Name _____

Company _____

Position _____

Address _____

City _____ State _____

ALLIED PAINT MFG. COMPANY
P. O. Box 1088, Tulsa, Okla.

BENNETT'S
65 W. First South St.,
Salt Lake City 10, Utah

WALTER N. BOYSEN CO.
42nd & Linden Sts., Oakland 8, Calif.
2309 E. 15th St., Los Angeles, Calif.

BRITISH AMERICAN PAINT CO., LTD.
P. O. Box 70, Victoria, B. C., Canada

BROOKLYN PAINT & VARNISH CO., INC.
50 Jay Street, Brooklyn 1, N. Y.

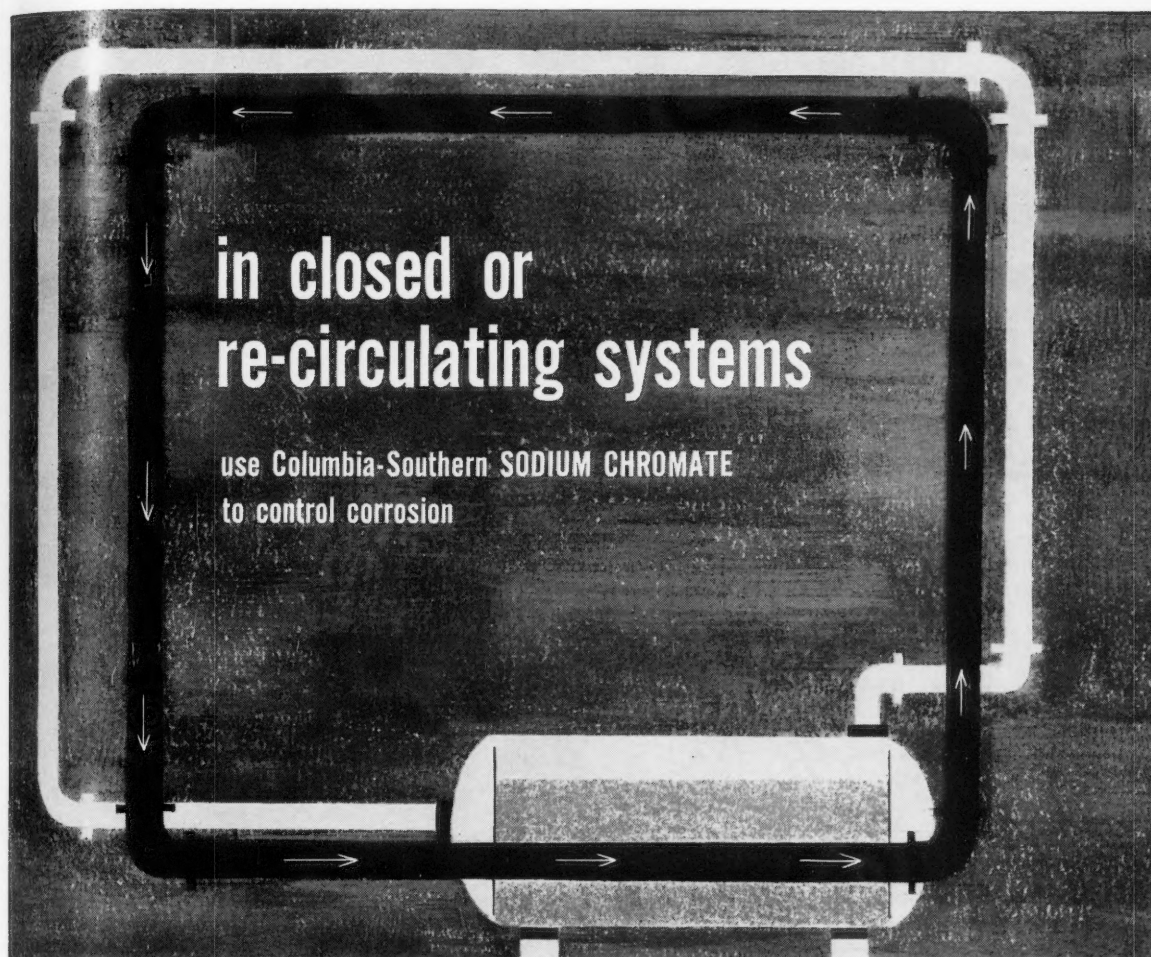
COAST PAINT & LACQUER CO.
P. O. Box 1113, Houston 1, Texas

ENTERPRISE PAINT MANUFACTURING CO.
2841 S. Ashland Ave., Chicago 8, Ill.

HANNA PAINT CO., INC.
P. O. Box 3206, S. H. Station,
Birmingham 5, Ala.

KOHLER-McLISTER PAINT CO.
P. O. Box 546, Denver 1, Colo.

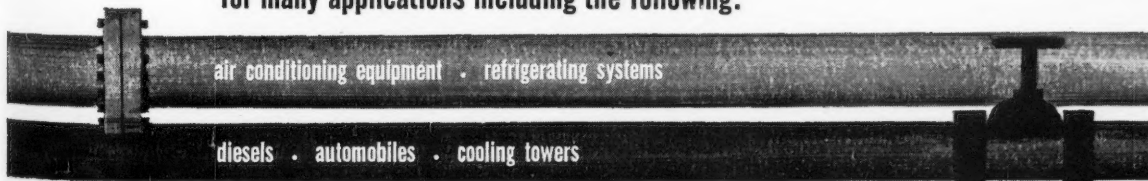
JAMES B. SIPE and COMPANY, INC.
P. O. Box 8010, Pittsburgh 16, Pa.



An excellent way to control corrosion in closed or re-circulating systems—effectively, economically and simply—is with Columbia-Southern Sodium Chromate.

Sodium Chromate inhibits corrosion through the formation of a thin film on the surface of the metal which protects the metal from chemical change. This film is self-renewing as long as sufficient chromate is present in the solution. If it is broken by abrasion, the chromate ions immediately seal it again.

Use Columbia-Southern Sodium Chromate with confidence for many applications including the following:



Write today for more information to Columbia-Southern Chemical Corporation at any of the district offices or at the Pittsburgh address.

SODIUM CHROMATE • SODIUM BICHROMATE • POTASSIUM BICHROMATE



**COLUMBIA-SOUTHERN
CHEMICAL CORPORATION**

SUBSIDIARY OF PITTSBURGH PLATE GLASS COMPANY
ONE GATEWAY CENTER • PITTSBURGH 22 • PENNSYLVANIA

DISTRICT OFFICES: Cincinnati • Charlotte • Chicago • Cleveland • Boston
New York • St. Louis • Minneapolis
New Orleans • Dallas • Houston
Pittsburgh • Philadelphia • San Francisco
IN CANADA: Standard Chemical Limited
and its Commercial Chemicals Division



News about COATINGS for METALS

Metallic Organic Decorative Protective

LARGE equipment now easily protected by dipping in plastisol

Steel drum can handle highly corrosive substances

Today's drum lining materials turn ordinary steel containers into containers suitable for chemically active products. With just four basic types of Unichrome linings, corrosion engineers can help solve problems of packaging such things as alkalis, oils, salts and their solutions, wetting agents, acid products, and many other corrosives.

It becomes a matter of matching the service requirements to the chemical and physical properties offered by Unichrome vinyl, phenolic, plastisol, and epoxy drum linings. Bulletin DL-2 gives useful data . . . or Metal & Thermit will gladly give its recommendations.

Neoprene delivers full-bodied film thickness in maintenance coatings

One Ucilon® Coating System based on an air-dry neoprene coating produces a film thickness of 3 mils per coat. Another, requiring force drying, provides a film of 5 mils or more per coat.

Such thicknesses, added to the well known resistance of neoprene to corrosives and oils, assure durable protection under severe service conditions. Send for data sheets.

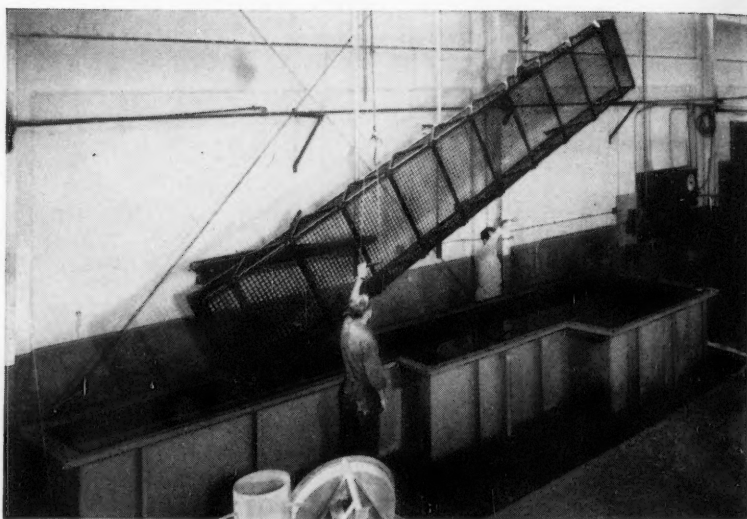
UNICHROME is a trademark of Metal & Thermit Corp.



METAL & THERMIT CORPORATION

General Offices: Rahway, New Jersey
Pittsburgh • Atlanta • Detroit
East Chicago • Los Angeles

In Canada: Metal & Thermit—United Chromium
of Canada, Limited, Toronto 1, Ont.



A huge 4,000 gallon dip tank for applying Unichrome Plastisol Coatings is in the plant of The Barber-Webb Co., Los Angeles. It has three widths, to accommodate various shapes.

PLASTISOL coatings grow more popular with each passing month. The more familiar that users become with the unusual corrosion protection and durability of these flexible, heavy duty vinyl coatings, the more new applications are developed.

Plants are therefore enlarging facilities to handle bigger and bigger equipment and products by dipping . . . the quickest and easiest method. Unichrome Series 4000 Plastisol Compounds are widely used to fill these tanks.

CORROSION BLOCKED

Unichrome Plastisols protect against acids, alkalis, alcohols, salt solutions, moisture, and a broad range of other chemically active compounds. When coated with a Unichrome Plastisol, ordinary metal parts and products are

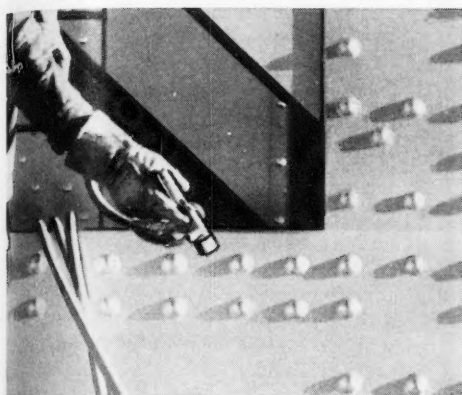
equipped to survive unusually severe service conditions.

UNIQUE PHYSICAL FEATURES

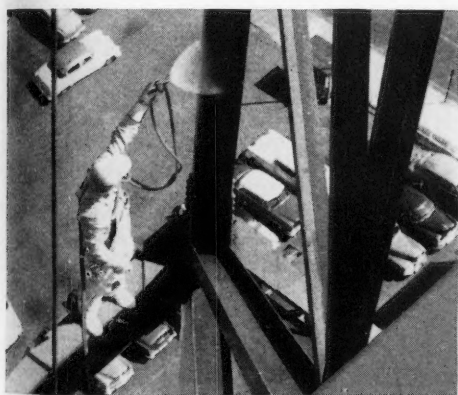
Unichrome Series 4000 Plastisol Compounds cure to flexible coatings which show great resistance to wear. They don't chip. They absorb impact, deaden sound, insulate electrically, and also look attractive. Depending upon the mass of the object being coated, they build a film thickness ranging from 3 mils to $\frac{3}{16}$ ". Heavier masses hold more heat and therefore get thicker coatings in dipping.

Unichrome Plastisols can be applied by all the other usual methods, too, including spraying. They're limited only by the facilities available to heat and hold the coated object at 350° to 365°F for curing. Send for Bulletin VP-1.

Get complete corrosion protection with one quick, easy spray application



When protective coatings are applied by the DeVilbiss spray method, ridges, recesses and uneven surfaces, like these protruding rivets, are thoroughly and uniformly sealed.



Hard-to-spray areas, like this radio tower, are coated in one application with DeVilbiss spray equipment. No damage claims either, thanks to new, fast-drying coating materials.



DeVilbiss equipment will spray all types of anti-corrosion coatings—aluminum, vinyl, mastic, asphalt. Note the toughness of this heavy, spray-applied Plastisol coating.

The DeVilbiss spray method penetrates hard-to-reach areas . . . provides even, protective coatings for irregular surfaces . . . simplifies application of extra heavy coatings.

When applied by the DeVilbiss spray method, protective coatings look better, wear better. That's because spraying under pressure penetrates and covers every surface pore, crack, and crevice with an even, uniform coating. *Result: longer-lasting protection against corrosion!*

Uniform coverage for rough surfaces!

Brushing and other methods of application often result in uneven coatings. This is especially true on corners, ridges and rough surfaces which are generally wiped thin. In contrast, the DeVilbiss spray method ensures a heavy, uniform film build on all surfaces.

Complete coverage for "inaccessible" surfaces!

Areas which are "inaccessible" by brush or ordinary applicators, are easy to coat by the DeVilbiss spray method. What's more, spray-coating this type of area is at least four times faster, produces a more uniform coating, and reduces the extra labor of reaching or dipping to carry the paint to the surface.

For full information on the DeVilbiss line of spray equipment, air compressors, hose and connections, call your nearest DeVilbiss supplier today.

THE DEVILBISS COMPANY Toledo 1, Ohio

Santa Clara, Calif. • Barrie, Ontario
London, England

Branch Offices in Principal Cities

FOR BETTER SERVICE, BUY

DEVILBISS



THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

- (a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- (b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- (h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.



Officers, 1956-57

<i>President</i>	W. F. FAIR, JR.
<i>Vice-President</i>	W. H. STEWART
<i>Treasurer</i>	R. A. BRANNON
<i>Executive Secretary</i>	A. B. CAMPBELL
	1061 M & M Bldg., Houston 2, Texas

Directors

President

W. F. FAIR, JR. 1956-57
Tar Products Div., Koppers Co., Inc., Pittsburgh, Pa.

Vice-President

W. H. STEWART. 1956-57
Sun Pipe Line Co., Beaumont, Texas

Treasurer

R. A. BRANNON. 1956-57
Humble Pipe Line Company, Houston, Texas

Past-President

FRANK L. WHITNEY, JR. 1956-57
Monsanto Chemical Co., St. Louis, Mo.

Representing Active Membership

HUGH L. HAMILTON. 1956-59
The A. V. Smith Engineering Co., Narberth, Pa.
A. L. STEGNER. 1956-59
Tennessee Gas Transmission Co., Houston, Texas
A. D. SIMPSON, JR. 1955-58
United Gas Corporation, Houston, Texas
THOMAS P. MAY. 1954-57
The International Nickel Co., Inc., New York, N. Y.

Representing Corporate Membership

H. L. BILHARTZ. 1956-59
Production Profits, Inc., Dallas, Texas
C. G. MUNGER. 1955-58
Amercoat Corp., South Gate, Cal.
ROBERT R. PIERCE. 1955-58
Pennsylvania Salt Mfg. Co., Philadelphia, Pa.
JACK W. HARRIS. 1954-57
Rockwell Manufacturing Co., Houston, Texas
H. R. BROUGH. 1954-57
Mountain Fuel Supply Co., Salt Lake City, Utah

Representing Regional Divisions

H. F. HAASE. (North Central) 1956-59
Milwaukee, Wis.
H. E. WALDRIP. (South Central) 1956-59
Gulf Oil Corporation, Houston, Texas
A. R. MURDISON. (Canadian) 1956-59
Imperial Oil Company, Ltd., Toronto, Ont.
ROBERT H. KERR. (Western) 1955-58
Southern California Gas Co., Los Angeles, Cal.
E. P. TAIT. (Southeast) 1954-57
Alloy Steel Products Co., Inc., Atlanta, Ga.
GEORGE E. BEST. (Northeast) 1954-57
Mutual Chemical Division,
Allied Chemical & Dye Corp., Baltimore, Md.

Directors Ex Officio

H. C. VAN NOUHUYS, Chairman Regional
Management Committee
Southeastern Pipe Line Co., Atlanta, Ga.
E. P. NOPPEL, Chairman Policy and Planning
Committee
Ebasco Services, Inc., New York, N. Y.
THOMAS P. MAY, Chairman Publication Committee
International Nickel Co., Inc., New York, N. Y.
C. P. LARRABEE, Chairman Technical Practices
Committee
U. S. Steel Corp., Monroeville, Pa.

Topic of the Month

Aluminum Armor Protects Power Cables

By D. M. FARNHAM*

METALLIC ARMORS are placed on underwater power cables to provide mechanical protection to the underlying lead sheath. Usually the armor of multi-conductor cable consists of galvanized steel wire spirally wrapped over a bedding of impregnated jute which has been placed over the lead sheath of the cable. This type of armor has proved to be of value in protecting the lead mechanically. It also has been useful from the corrosion standpoint.

When high voltage circuits capable of carrying large amounts of power are installed they are constructed of single conductor cables laid parallel to each other. The use of steel or other magnetic material as armor on single conductor cables is undesirable inasmuch as the electrical losses due to induced currents are high and the current carrying capacity of the cables is adversely affected. Under these circumstances a non-magnetic material having good electrical conductivity is preferred. Aluminum offers these properties.

When the 35 mile cable crossing of the St. Lawrence River was in the design stage, a decision was made to use aluminum alloy 57S as the armor material. Aluminum alloy had been used for similar purposes for many years for both power cables and telephone cables. One of the first instances occurred some 20 years ago on a cable in Ireland manufactured by W. T. Henley's Telegraph Company, Limited. When a piece of this cable was removed

from the sea a year or so ago for observation the armor showed no severe corrosion by the salt water. On the basis of test data supplied by the Aluminum Company of Canada and the Canada Wire and Cable Company, aluminum alloy 57S resists corrosion by salt water. It also possesses the electrical conductivity needed for the particular circuit characteristics and the tensile strength required for the laying operation. The lightness of aluminum permitted the deep sea portion of each cable (26 miles) to be made and handled in one piece.

Each of the four cables consists of a copper conductor surrounded with oil-impregnated paper insulation and 0.105-inch thick lead sheath. Over the lead sheath is a bedding of insulating material and 26 aluminum alloy wires 0.294-inch in diameter forming the armor. At the shore ends, the aluminum armor is connected electrically to the lead cable sheath and grounded. Although the aluminum is anodic with respect to lead, the relatively large amount of aluminum would indicate a large anode area and consequently a relatively small intensity of corrosion current. The worst corrosion would be expected to occur, if at all, at the shore ends near the junction with the land cable. The potential of the armor would be the potential of the water, while the sheath would vary in potential depending on electrical constants and current carried by the conductor.

A recent inspection of the shore ends after two years in place showed no signs that corrosion of the armor had occurred since the cable was installed.

*Quebec Hydro-Electric Commission.

TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Laboratory Method for Corrosion Inhibitor Evaluation*

By G. A. MARSH and E. SCHASCHL

Introduction

CORROSION SYSTEMS in which two or more phases are present are common in the petroleum industry in such diverse forms as oil wells, refinery streams, and tanker ships. With increasing application of corrosion inhibitors to such systems, methods for inhibitor evaluation are worthy of considerable attention.

In recent years, product soluble inhibitors ("gasoline rust inhibitors") have been developed for corrosion protection of pipe lines and tanker ships. Laboratory evaluation of these inhibitors has been done most frequently by means of some modification of the ASTM D-665-54 turbine oil rust test.¹ This test, while well suited to its original purpose, has been found by a number of laboratories² to be unsatisfactory for evaluating gasoline rust inhibitors.

The principal objections to the modified ASTM test are that it is qualitative and that it is somewhat subjective. The technique of the operator in polishing the metal specimen may affect the resulting rating. Other objections are that the test is sometimes not reproducible, and that it is rather mild. The test also may not distinguish between inhibitors and detergent materials which prevent rust from adhering to the metal specimen. However, the qualitative aspect alone makes the test unattractive when one attempts to compare inhibitors.

A more severe test which was considered for gasoline rust inhibitor evaluation was the Navy static water drop test.³ Like the ASTM turbine oil rust test, the Navy test can be modified in several ways. But again the results are a matter of inspection and comparison of rust spots; quantitative results are lacking.

Several workers have recently applied a conductance method to this problem. Dravnieks and others of Standard Oil Company (Indiana)^{2,4} and Terrell and Lewis⁵ of Esso Standard Oil Company have both used a thin steel foil in place of the rod normally used in the ASTM test. They report satisfactory results provided the temperature is held constant within 0.1 degree F. The conductance method has the advantage that the metal cross section (and therefore loss in thickness resulting from corrosion) can be followed without the necessity for interrupting the test.

The test to be described here permits the course of corrosion to be followed directly on a meter in microinches loss of thickness. While this new test is based on the conductance method, close temperature control is unnecessary because of the design of



GLENN A. MARSH—Pure Oil Company, Research and Development Laboratories, Crystal Lake, Illinois. He received a BS in chemistry from Illinois Institute of Technology in 1945 and an MS in chemistry from Northwestern University in 1946. He began his employment with Pure Oil Co. in 1948 and is presently engaged in corrosion research.



EDWARD SCHASCHL—Pure Oil Company, Research and Development Laboratories, Crystal Lake, Illinois. He received a BS in chemical engineering from Illinois Institute of Technology in 1945 and joined Pure Oil Company in 1948 as a process engineer. He is presently doing research in metallurgy and corrosion.

Abstract

A screening method has been developed which permits rapid, convenient testing of inhibitors. Unlike weight-loss methods, this new method is well adapted to follow non-linear corrosion-time curves, such as those commonly found when adsorption-type inhibitors are used. The method makes use of quart bottles containing the corrosive agents; the bottles are rotated end over end at about three rpm. This rotation brings about alternate immersion of test probes where the corrosive system consists of two or more phases. The test probes are used to follow the course of corrosion without requiring the bottles to be opened. A probe consists of a corroding specimen (metal ribbon) to which is attached a protected specimen serving as a temperature-compensating element. These specimens form two arms of a resistance-measuring bridge. Electrical leads, brought through the rubber stopper to the outside of the bottle, permit the probe to be connected when desired to a bridge circuit which internally converts any change in resistance to loss of metal thickness. The corrosion loss in millionths of an inch is read directly from a meter and can be followed conveniently during the course of the test. An application of the method in testing gasoline rust inhibitors is discussed.

58.1

the corrosion sensing element or probe. The test appears to be more severe than the modified ASTM turbine oil rust test; this is desirable when studying tanker corrosion inhibitors. The method also is adaptable to testing inhibitors for other multiphase corrosion systems, including some where higher temperatures and pressures are involved.

* Submitted for publication March 27, 1956. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.

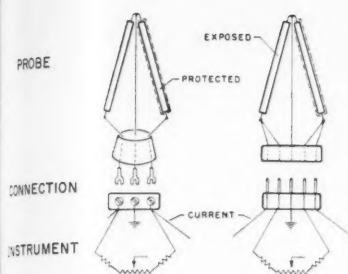


Figure 1—Temperature compensated corrosion test probe.



Figure 2—High pressure corrosion test probe.



Figure 3—Pure Oil corrosion meter.

In this article, the temperature-compensated probe, the measuring circuit and the associated equipment and method will be briefly reviewed. A comparative study of two gasoline rust inhibitors will illustrate the type of information yielded by this method.

Temperature Compensated Probe

The temperature compensated probe, which is the subject of patent applications, has been described in a previous communication from The Pure Oil Company Research and Development Laboratories.⁶ The probe consists of a test element which is exposed to the corrosive environment, and a protected element which is the same kind of metal as the test element but which is insulated from the corrosive environment. The two elements are connected to form arms of a Wheatstone bridge. The assembly is made into the form of a probe which can be inserted into the corrosive environment. Figure 1 (left) shows a schematic sketch of a probe on a rubber stopper, suitable for inserting into a bottle. Figure 2 shows a more rugged probe suitable for insertion into a refinery stream.

It will be noted that the probe construction provides compensation for temperature and also compensation for thermo-electric effects. Electrical leads coming out allow corrosion measurements to be made while the probe is installed. If desired, a male-female plug and socket arrangement can be used to make the connections with minor modification in the probe design as shown in Figure 1 (right).

The Measuring Circuit

The direct-reading corrosion meter has been described previously⁶ and is the subject of patent applications. Unlike most of the conductance techniques recently reported, this instrument employs 60 cycle AC instead of direct current. The use of AC permits high amplification; in fact only a few tenths of a millivolt are applied across the test element. Polarization effects, which greatly affect DC conductance measurements in some solutions, are eliminated.

By means of suitable electronic amplification and calibration, the measuring circuit provides a direct reading meter from 0 to 100 microinches loss of

thickness. The calibration is independent of the probe being used; this makes it possible to test a large number of corrosion probes with a single measuring instrument in a very short time. As the meter is direct-reading, there is no complicated mass of dials or arithmetic involved; everyone who uses the instrument gets the same answer. Some errors inherent in coupon testing are eliminated. The meter is shown in Figure 3.

The instrument and probes are suitable for studying almost any corrosive condition and are not limited to the rotating bottle test described here. The use of the instrument and probes for field and plant testing are apparent but are beyond the scope of this paper.

Rotating Bottle Apparatus and Test Method

The temperature compensated probe could be used as is for a type of quantitative modified ASTM turbine oil rust test. It seemed interesting, however, to explore a method which would lend itself to a wider variety of multiphase corrosion tests. The method finally developed is a rotating bottle test in which the two liquid phases are placed in a quart bottle, in the desired ratio, and a probe is used to follow the corrosion. As the bottle is rotated end over end, the probe is alternately immersed in the two components. The space at the top of the bottle can be filled with air or other gas to maintain desired conditions. By using plastic-lined or glass-lined bombs instead of bottles, the range of the test can be extended upward in both temperature and pressure. As no close temperature control is required for use of the probes, the tests can be carried out at room temperature, if that temperature is in the desired range.

Figure 4 shows a 20 bottle machine installed in the Pure Oil Company Research and Development Laboratories. Readings can be made as fast as the instrument can be connected to the probes. The loss in metal thickness also can be continuously recorded on a strip chart recorder if desired. Because of the low voltage AC applied to the probe, there is no change in reading as the probe is alternately immersed in liquids of different conductivity (e.g., in gasoline and brine.)

The rotating bottle test was used to study gasoline rust inhibitors such as would be used on ocean-going

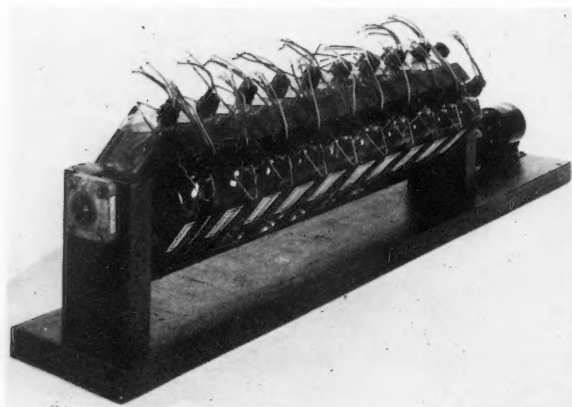


Figure 4—Rotating bottle apparatus.

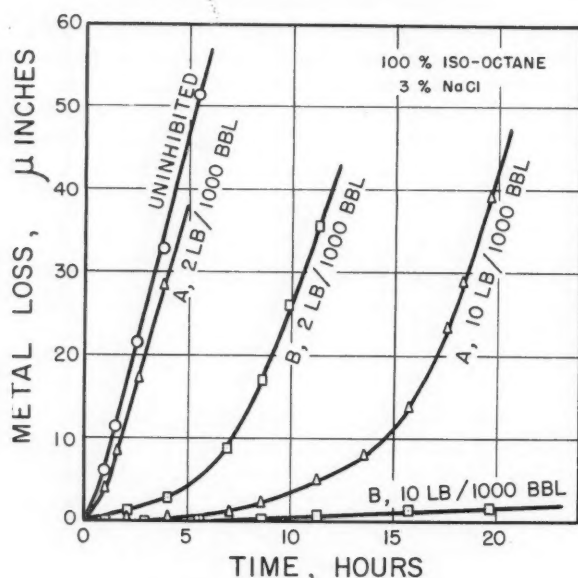


Figure 5—Typical inhibitor test data.

tankers. The experiments to be described were chosen to illustrate the type of data obtainable with this method. In these experiments, 450 cc each of brine and inhibited hydrocarbon were added to a quart bottle, leaving a 70 cc air space. A probe was inserted and the bottle was rotated end over end at 3 rpm. At intervals of from $\frac{1}{2}$ to 8 hours, depending on the corrosion rate, the meter was read to establish the corrosion loss.

Comparison of Gasoline Rust Inhibitors

Figure 5 shows the actual meter readings (in microinches loss of thickness of steel) as a function of time, for several concentrations of inhibitors A and B and also for the blank (uninhibited) run. In these tests the brine was 3 percent NaCl; the hydrocarbon was iso-octane. It will be noted that after a period of time the curves ended up parallel with the blank curve. This presumably was due to adsorption of inhibitor onto the rust particles, with eventual depletion of the inhibitor available to repair the film on

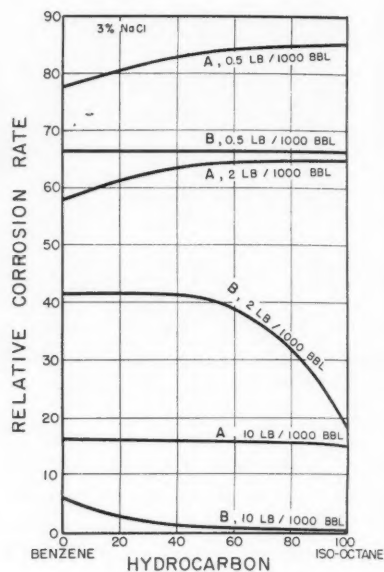


Figure 6—Relation of hydrocarbon composition to inhibitor effectiveness.

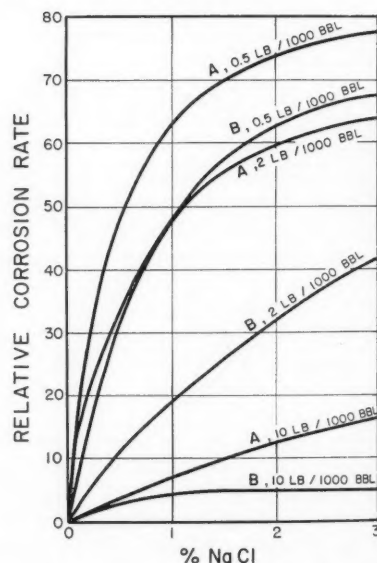


Figure 7—Effect of brine concentration on inhibitors with benzene as hydrocarbon phase.

the metal. The time required for this disruption of the film was quite reproducible in this test with some inhibitors but rather poorly reproducible with others. For screening purposes, duplicate runs were made with all inhibitors.

The data of Figure 5 require no interpretation so far as choosing the better inhibitor is concerned. However, to make additional studies it was desired to express a number, or a "corrosion rate" associated with each run. This perhaps could be done by choosing the initial slope of the corrosion time curve, before the curve rises steeply at the uninhibited rate. Attempts to use the initial slope soon showed that this slope did not differentiate between some curves that were quite different in appearance. For this rea-

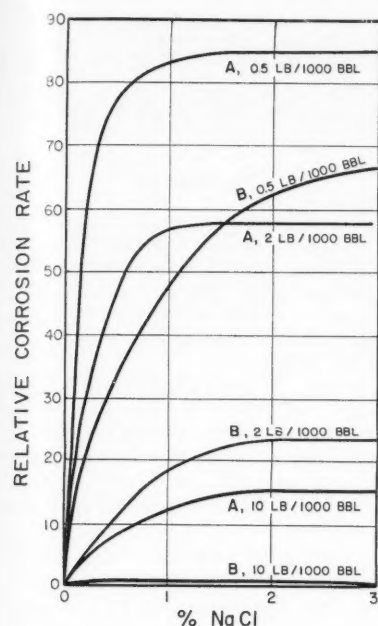


Figure 8—Effect of brine concentration on inhibitors with iso-octane as hydrocarbon phase.

son the authors feel that the initial slope method used in other conductance tests^{2,5} might not always give the correct result. The "corrosion rate" finally chosen was the slope of the corrosion-time curve, assuming linearity between 0 and 20 microinches loss. This appears to be somewhat artificial, as the curves are seldom truly linear in this range. In spite of this deficiency, however, the corrosion rate thus obtained seems to be a good relative value on which to compare the effectiveness of inhibitors.

Effects of Inhibitor Concentration, Brine Composition, and Hydrocarbon Composition

The inhibitors were somewhat sensitive to hydrocarbon composition, but not extremely so, as indicated by Figure 6. Inhibitor A worked better in benzene; B in iso-octane. The use of gasoline was avoided after it was found that both the rotating bottle test and actual tanker tests gave variable results with different batches of gasoline, even though runs in each batch were self consistent.

Figures 7 and 8 illustrate the effect of salt concentration on the corrosion rate. In Figure 7 with benzene as the hydrocarbon phase, 3 percent NaCl was definitely the most corrosive brine composition. In Figure 8, with iso-octane as the hydrocarbon phase, there was little or no difference in corrosion rate in the 1.5 percent and 3 percent NaCl solutions.

Comparison of Tanker and Laboratory Results

Figure 9 illustrates the difference in quality between inhibitors A and B. In iso-octane, 11.5 pounds of A would be required to inhibit to the same level as 6 pounds of B (per 1000 barrels hydrocarbon), based on the rotating bottle test results.

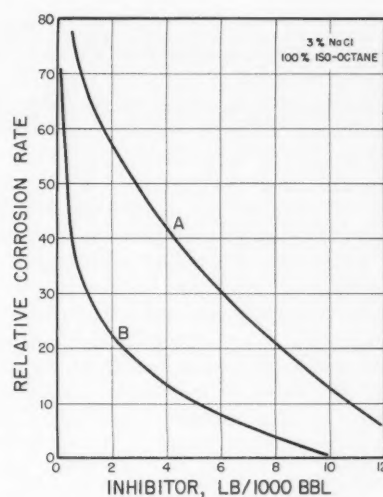


Figure 9—Effectiveness of corrosion inhibitors based on rotating bottle test.

Two full scale tests were then run, using 11 pounds and 13 pounds of A and 6 pounds of B per 1000 barrels of gasoline, in separate tanks of a T-3 tanker operating in the Gulf-East Coast route. The corrosion rates in inhibited and in uninhibited tanks were followed with probes, using a technique reported previously.⁷

The results of these tanker tests are given in Table 1. From the tanker tests, one would conclude that 6 pounds of B per 1000 barrels of gasoline is equivalent in corrosion protection to about 12 pounds of A, which is in agreement with the laboratory test data of Figure 9.

Figure 9 can be replotted, using cost data, to determine the probable cost of achieving a certain level of protection.

Conclusion

A rotating bottle test has been described, using as an example the comparison and evaluation of two gasoline rust inhibitors. The test method appears to be of value in reproducing the basic mechanism of corrosion where several phases are involved. In the case of the gasoline rust inhibitors, the test takes into account to some degree (1) the necessity of preserving the inhibitor film in the presence of highly aerated water (i.e., competition between water and inhibitor for adsorption onto the steel), (2) effect of brine solubility on inhibitor effectiveness, and (3) effect of rust particles on the adsorption of inhibitor onto the steel. The test is more severe than the modified ASTM turbine oil rust test because there is al-

TABLE 1—Comparison of Laboratory and Tanker Corrosion Tests

Inhibitor	Equivalent Dosage Based on Lab. Test (lb./1000 bbl. Gasoline)	TANKER TEST No. 1		TANKER TEST No. 2	
		Dosage Used	% Reduction in Corrosion After 60 Hours	Dosage Used	% Reduction in Corrosion After 60 Hours
A	11.5	11	70-80	13	85-95
B	6.	6	80-90	6	80-90

most no agitation. Repair of an inhibitor film in any case requires that a supply of inhibitor molecules be available at the metal surface. In the ASTM test, rather violent agitation can actually aid repair of the film, while in the rotating bottle test the inhibitor must move partly by diffusion.

The test has been used successfully for other studies where alternate exposure of steel in two liquid phases appears to simulate the corrosive conditions. If the basic mechanism of corrosion can be reproduced by such alternate exposure, the test can be expected to correlate well with field experience.

Considering the convenience and unique remote reading feature of the probe method for corrosion testing, the method may eventually displace coupon weight loss testing to some extent. A limitation which is common to both coupon and probe method will bear repeating: because of the small size of the specimens, the corrosion rates are not necessarily the same as those of a larger structure having the same exposure. For this reason, these tests should be designed as comparative tests whenever practicable.

**Any discussions of this article not published above
will appear in the December, 1956 issue.**

Acknowledgment

The corrosion meter circuit was designed by L. E. Ellison. Tanker corrosion data were obtained by A. L. Widerquist.

References

1. ASTM D-665-54, Standard Method of Test for Rust-Preventing Characteristics of Steam-Turbine Oil in the Presence of Water. ASTM Standard, 1955, Part 5, p. 294.
2. A. Dravnieks and H. A. Cataldi. *Corrosion*, **10**, 224 (1954); also U. S. Patent 2,735,754.
3. H. R. Baker, D. T. Jones, and W. A. Zisman. *Ind. Eng. Chem.*, **41**, 137 (1949).
4. A. J. Freedman, A. Dravnieks, W. B. Hirschmann and R. S. Cheney. Paper presented at NACE Twelfth Annual Conference, N. York, N. Y., March 13, 1956.
5. W. L. Terrell and W. L. Lewis. *Corrosion*, **12**, 491t (1956) Oct.
6. G. A. Marsh and E. Schaschl. *Oil and Gas Journal*, **54**, No. 29, 135 (1955) Nov. 21.
7. G. A. Marsh and A. V. Koebley, Jr. *Oil and Gas Journal*, **54**, No. 29, 139 (1955) Nov. 21.

A Simple Phase Equilibrium Approach To the Problem of Oil-Ash Corrosion*

By W. R. FOSTER, M. H. LEIPOLD and T. S. SHEVLIN

Introduction

METAL CORROSION by residual fuel-oil ash has become a vexing problem in the operation of the modern gas turbine engine.^{1,2,3,4} Of related interest is the slagging of the refractories of navy boilers.^{5,6} It is commonly agreed that corrosion is in some manner related to the sodium, sulfur and vanadium content of the residual ashes deposited on the metal during combustion of the fuel oil. There has been a definite trend toward higher and higher content of these elements in residual fuel oils over the past 20 years.⁷ The problem therefore is becoming more and more acute.

In a number of recent investigations of oil-ash corrosion of metals a simplification of the analysis of the problem has been sought through a study of the effects of a series of mixtures of sodium sulfate and vanadium pentoxide.^{8,9,10,11,12,13} In view of the predominance of sodium, sulfur, and vanadium in typical analyzed ashes^{3,9,14,15} such a simplification would appear to be justified. Yet even the numerous studies of these simplified ashes have not resulted in a consistency of view as to the specific agents of corrosion. In some instances corrosion has been attributed to the influence of either or both of the end members (Na_2SO_4 and V_2O_5). In others, the action of a number of known sodium vanadate compounds has been invoked. In still other cases the formation of complex sodium sulfate-vanadium pentoxide compounds has been postulated.

In view of the conflicting opinions regarding the behavior of Na_2SO_4 - V_2O_5 ashes, no clear understanding of their role in corrosion is presently possible. It occurred to the authors that if these ashes were considered in terms of a possible ternary system Na_2O - SO_3 - V_2O_5 , some clarification might result. Experiments were devised accordingly to investigate the compatibility relationships in the system Na_2O - SO_3 - V_2O_5 at temperatures of interest to oil-ash corrosion investigators. The compatibility diagram resulting from such a study could then be used to analyze the results of previous and current investigations of the corrosion problem.

Theoretical Possible Configurations for the System Na_2O - SO_3 - V_2O_5

To the authors' knowledge, no phase equilibrium diagram of any kind has ever been published for the system Na_2O - SO_3 - V_2O_5 . For this reason it became necessary, as a preliminary step, to ascertain all of the various ways in which the system could theoretic-

Abstract

Many recent investigations of residual fuel oil-ash corrosion have utilized simulated ashes based upon mixtures of Na_2SO_4 and V_2O_5 . Results of these various studies have not always been easily correlated. It was reasoned that a knowledge of the phase equilibrium relationships in the system Na_2O - SO_3 - V_2O_5 might provide a reliable basis for the comparison and evaluation of such studies. Accordingly, a compatibility diagram was deduced for the system. Volatilization experiments and phase identification by microscopic and x-ray methods confirmed the essential validity of the diagram. When used as a background for the consideration of previous and current oil-ash corrosion research, the diagram was found to be consistent with most of the recorded findings.

It has been found that Na_2SO_4 and V_2O_5 are not compatible with each other in either the crystalline or molten state. They react upon heating with evolution of SO_3 to form NaVO_3 , as well as several complex vanadates, but not Na_3VO_4 or $\text{Na}_4\text{V}_2\text{O}_7$. The complex vanadates cause the most severe attack of any of the possible corrodents. Vanadium pentoxide, previously credited with a major role in oil-ash attack, emerges as a relatively unimportant corrodent, since V_2O_5 as such is absent from all but a few fuel-oil ashes. The only simple sodium vanadate which might function in oil-ash corrosion is NaVO_3 . There are indications that despite its 74.6 percent content of V_2O_5 , its attack is usually mild. Sulfur trioxide, which has received little attention in high temperature corrosion studies, has given evidence of potentially severe corrosion. In ashes of high sodium-vanadium ratio, some sodium sulfate persists without decomposition, and in such cases may participate in the attack. 3.5.9.

cally be subdivided into compatibility triangles. That done, each of the resulting configurations could be examined in turn, in order to determine which of the various possibilities were valid for the system. The simple principles involved in the selection of the subdivision which is compatible with equilibrium relationships in the system, have been outlined in some detail elsewhere.^{16,17}

Before proceeding with such a step, however, it was necessary to come to a decision as to which of the recognized compounds involving Na_2O , SO_3 , and V_2O_5 might be expected to merit consideration. It is pertinent in this connection that oil-ash corrosion studies have been carried out generally in the temperature range 1300-1700 F. It would seem reasonable therefore to eliminate from consideration any compounds which had no stable existence in this temperature range. Sodium pyrosulfate ($\text{Na}_2\text{S}_2\text{O}_7$), which decomposes at about 860 F, would fall into this category and probably also would VOSO_4 and $(\text{VO})_2(\text{SO}_4)_3$. Elimination of these three compounds would leave Na_2SO_4 , and the three simple sodium

* Submitted for publication April 23, 1956.



W. R. FOSTER is an associate professor of mineralogy at Ohio State University. He has chemistry degrees from the University of New Brunswick and the Catholic University of America, and a PhD in geology from the University of Chicago. A former petrographer for the Champion Spark Plug Company, he has taught at Catholic University and Pennsylvania State University. He is a member of Sigma Xi, and a fellow of the American Mineralogical Society, the American Ceramic Society, and the Ohio Academy of Science.

M. H. LEIPOLD is a research associate in the Ohio State University's Engineering Experiment Station, where his work has been mainly concerned with corrosion by residual fuel oil ashes. He was formerly employed as a research engineer by Industrial Development Laboratories, Jersey City, N. J. He has ceramic engineering degrees from Rutgers University and Ohio State and is currently working toward a doctoral degree. He is a member of Sigma Xi and the American Ceramic Society.



T. S. SHEVLIN is a research associate in the Engineering Experiment Station of Ohio State University and assistant professor of ceramic engineering. He is the author or co-author of numerous papers, as well as more than 50 reports to Air Force laboratories, on the development and testing of cermet bodies. A registered professional engineer, he holds three degrees from Ohio State. He is a member of Sigma Xi, the American Ceramic Society and the Institute of Ceramic Engineers.



vanadates (Na_3VO_4 , $\text{Na}_4\text{V}_2\text{O}_7$, and NaVO_3) to be incorporated into the compatibility diagram.

The four separate and distinct ways in which the above compounds may enter into compatibility relationships with one another and with the constituent oxides, Na_2O , SO_3 and V_2O_5 , are shown in Figure 1. The location of the Na_2SO_4 - V_2O_5 series is indicated in each diagram by linearly arranged crosses.

It is interesting to note that only one of the four possible diagrams in Figure 1 (diagram a) represents Na_2SO_4 and V_2O_5 as compatible with each other. Each of the other three calls for the interaction of Na_2SO_4 and V_2O_5 to yield products other than the starting materials or the additive compounds thereof. Careful study of heat-treated Na_2SO_4 - V_2O_5 mixtures should permit an unequivocal selection of the one valid diagram. Thus, if Na_2SO_4 and V_2O_5 remained as such on cooling the heat-treated mixtures, and if there had been no significant evolution of SO_3 , diagram (a) would be indicated. If, on the other hand, appreciable liberation of SO_3 occurred during the heat-treatment of Na_2SO_4 and V_2O_5 , with the accompanying formation of other new phases, the valid configuration would necessarily be one or another of diagrams (b), (c), or (d). Which of these latter three represented the actual compatibility relations would of course depend on which phases were produced from the various Na_2SO_4 - V_2O_5

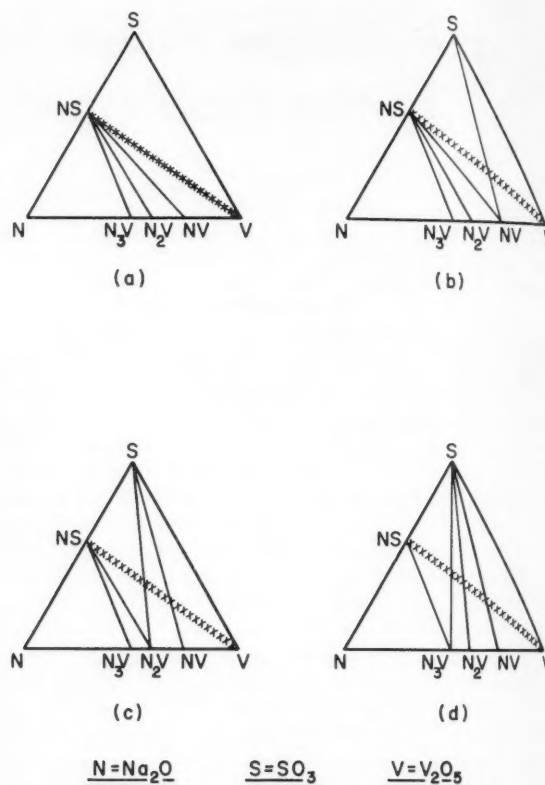


Figure 1—Four possible compatibility diagrams for the system Na_2O - SO_3 - V_2O_5 .

TABLE 1—Synthetic Ashes

ASH	WEIGHT PERCENT	
	Na_2SO_4	V_2O_5
A	50	50
B	26	74
C	74	26

mixtures. For example, a mixture of starting composition 80 Na_2SO_4 -20 V_2O_5 would point to diagrams (b), (c), or (d) according to whether the heat-treatment resulted in: (1) Na_2SO_4 , SO_3 , and NaVO_3 ; (2) Na_2SO_4 , SO_3 , and $\text{Na}_4\text{V}_2\text{O}_7$; or (3) Na_2SO_4 , SO_3 and Na_3VO_4 .

Investigation of Compatibilities in the System Na_2O - SO_3 - V_2O_5

Mixtures Studied

In the course of a systematic study of the corrosion resistance of various alloys, cermets, and ceramic bodies, three synthetic ashes were selected for the corrosion tests. The weight-ratio of Na_2SO_4 to V_2O_5 in these ashes⁽¹⁾ is given in Table 1. These ashes were compounded from Na_2SO_4 (J. T. Baker Reagent grade anhydrous powder) and V_2O_5 (Coleman and Bell, Reagent grade granules). The same ash compositions were used in the equilibrium

(1) Each ash contained also 5 percent of carbon (lamp black) but this, for present purposes, may be disregarded.

studies under discussion. The same heat-treatment as that involved in the corrosion resistance studies (25 hour heating at 1600 F in unglazed mullite crucibles in a large electric heat-treating furnace) was likewise employed. Any conclusions arrived at from these studies should thereby be more directly applicable to the corrosion studies.

For certain aspects of the study it was deemed advisable to investigate a more extended series of compositions. Accordingly, the mixtures listed in Table 2 were prepared.

Finally, as it became apparent that the mixtures included in Tables 1 and 2 were inadequate for the clarification of certain aspects of the phase identification problem, a further set of supplementary mixtures was prepared (Table 3).

The last six mixtures were compounded from NaVO_3 and V_2O_5 , and correspond to the theoretical molecular ratios NV_2 , N_2V_5 , NV_3 , NV_4 , NV_5 , and NV_6 , respectively (where $\text{N} = \text{Na}_2\text{O}$ and $\text{V} = \text{V}_2\text{O}_5$).

Volatilization Studies

Because of a lack of optical and x-ray data on anhydrous compounds of V_2O_5 , initial efforts toward positive phase identification were unsuccessful. Nevertheless it soon became apparent that the heat-treated mixtures of Na_2SO_4 and V_2O_5 could not be interpreted as mere mechanical mixtures of the end-members. The obvious formation of new and different, even though unidentified, phases suggested two possibilities: (1) that Na_2SO_4 and V_2O_5 react to form additive compounds as recently proposed,¹² and (2) that Na_2SO_4 and V_2O_5 react with the evolution of SO_2 to form one or more sodium vanadates. It was a simple matter to decide between the two alternatives.

A series of eight weighed mixtures (Table 2) was subjected to 1600 F, and weight losses after 24 and 120 hours were determined and plotted in Figure 2. It is obvious that these results are incompatible with the first of the two hypotheses presented above. Three additional curves (overlying one another in the high- V_2O_5 region) appear in Figure 2. These depict the theoretical weight losses calculated for interaction of Na_2SO_4 and V_2O_5 to form (1) NaVO_3 , (2) $\text{Na}_4\text{V}_2\text{O}_7$ and NaVO_3 , and (3) Na_3VO_4 , $\text{Na}_4\text{V}_2\text{O}_7$ and NaVO_3 , in accordance with Figure 1, diagrams b, c, and d respectively.

The close approximation of the experimental weight losses to those calculated for the formation of

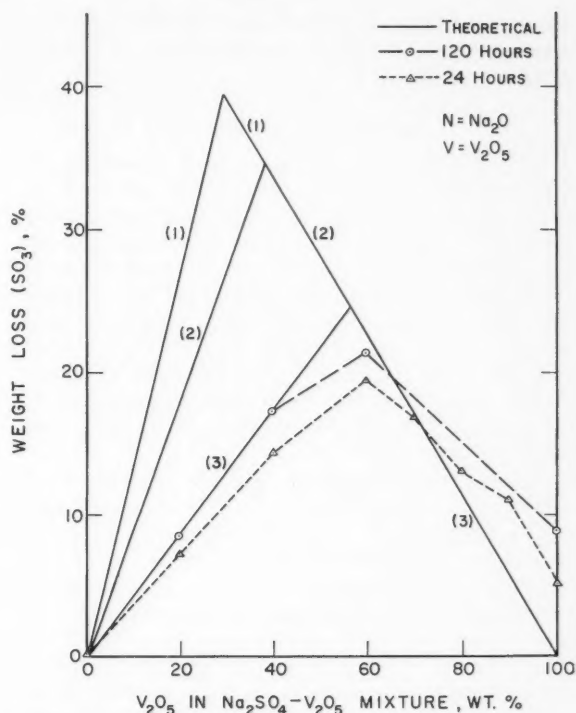


Figure 2—Experimental weight losses from $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixture at 1600 F and theoretical weight losses based upon considerations depicted by the curves as follows: Curve 1— $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ series forms Na_3V , N_2V and NV (would validate Figure 1d); Curve 2— $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ series forms N_2V and NV (would validate Figure 1c); Curve 3— $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ series is unreactive or forms additive compounds (would validate Figure 1a). Experimental curves support ideal Curve 3.

TABLE 3—Supplementary Mixtures

Na_2SO_4 , Wt. %	Na_2O , Wt. %	V_2O_5 , Wt. %
70	...	30
18	...	82
16	...	84
14	...	86
11.2	...	88.8
5	...	95
3	...	97
1	...	99
...	14.5	85.5
...	12.0	88.0
...	10.2	89.8
...	7.8	92.2
...	6.4	93.6
...	5.3	94.7

only one of the three simple vanadates (NaVO_3) is impressive. The deviation at the V_2O_5 end of the series can be accounted for largely by the direct loss of molten material, which has been observed to creep over the interior and exterior surfaces of the crucible, reacting ultimately with the refractory support. A crucible of V_2O_5 supported by a platinum bail so as to prevent such ultimate creep loss showed no weight loss in six hours at 1600 F. An identical test method showed that the 20 Na_2SO_4 -80 V_2O_5 mixture lost no weight during the 13½ hour interval between 25¼ and 27 hours of exposure at 1600 F. Therefore it is concluded that the experimental losses exceed the theoretical losses in the high V_2O_5 members of the series by reason of material loss through fluid creep.

TABLE 2—Mixtures Prepared for Volatilization Studies

MIXTURE	WEIGHT PERCENT	
	Na_2SO_4	V_2O_5
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60
6	60	40
7	80	20
8	100	0

It appears equally clear from these tests that the excessive losses are not to be attributed to loss of V_2O_5 by volatilization.

Identification of Phases

The volatilization studies outlined above helped greatly to remove the difficulties that had been encountered in preliminary attempts at phase identification. Ashes A, B, and C were re-examined in the light of these studies, by microscopic and x-ray powder diffraction techniques. Since it had become apparent that one or more sodium vanadates were involved in the heat-treated Na_2SO_4 - V_2O_5 series, specimens⁽²⁾ of Na_3VO_4 , $Na_4V_2O_7$ and $NaVO_3$ were secured. Direct examination of these compounds provided necessary optical and x-ray diffraction data otherwise unavailable.

Since the $Na_4V_2O_7$ sample, as received, proved to be a mixture of Na_3VO_4 and $NaVO_3$, attempts were made to synthesize the compound, but to no avail. Invariably, a mechanical mixture of the ortho and metavanadates was obtained, with no indication of any pyrovanadate. These observations might be construed as casting doubt on the existence of $Na_4V_2O_7$ as a stable compound. However, its appearance on the published phase diagram for the system Na_2O - V_2O_5 ¹⁸ suggests that it is a well-substantiated compound. Therefore the authors, for the present, attribute their unsuccessful efforts at synthesis to their failure to discover conditions favorable to its formation. Accordingly, belief in the existence of $Na_4V_2O_7$ is indicated in all subsequent discussion.

The results of the restudy of the three ashes are summarized in Table 4. There was no evidence, in any of the ashes, of phases which might be correlated with Na_3VO_4 or $Na_4V_2O_7$. This was not surprising in view of the deduction from the volatilization studies that $NaVO_3$ is the only simple vanadate formed from Na_2SO_4 - V_2O_5 mixtures.

The V_2O_5 -like phase observed microscopically in ash B gave an x-ray diffraction pattern unlike that of V_2O_5 . Four possibilities suggested themselves as to the nature of the unidentified phase: (1) that it was one of the less common of the three polymorphic forms of V_2O_5 ¹⁹ (2) that it was a simple vanadate other than one of the three currently recognized compounds shown in the phase diagram¹⁸ (3) that it was one of the recently postulated Na_2SO_4 : V_2O_5 addition compounds,¹² and (4) that it corresponded to one of a number of reported complex sodium vanadous-vanadic compounds.¹⁸ The fact that ash B consists very predominately of the unknown phase tentatively ruled out a form of V_2O_5 . The volatilization studies tended to discredit belief in a Na_2SO_4 : V_2O_5 addition compound. It thus appeared to be a matter of choosing between a simple or a complex sodium vanadate.

To facilitate a solution to the problem, a number of the mixtures listed in Table 2 were examined by x-ray powder methods. In addition, mixtures of $NaVO_3$ and V_2O_5 corresponding to the molecular formulas

NV_2 , N_2V_3 , NV_3 , NV_4 , NV_5 and NV_6 were prepared and fused (Table 3). Critical examination of x-ray powder films revealed not one, but two unknown patterns, suggesting two distinct compounds. As closely as could be determined, these two patterns showed their best development in mixtures NV_3 and NV_6 , respectively. The NV_3 -pattern displayed strong similarity to that of ash B.

As to the exact formulas of the two compounds the authors would care to do no more than speculate. One thing is certain: They are not additive compounds of Na_2SO_4 and V_2O_5 , because their preparation involved the use of $NaVO_3$ and V_2O_5 only. Certain phenomena tend to favor complex sodium vanadous vanadates, rather than simple sodium vanadates. Thus, both ash B and mixture NV_6 exhibited a peculiar behavior while solidifying from the melt. Gas was actively evolved, imparting a vesicular structure to the crystallized mass. A test for SO_3 was negative, but a glowing splinter burst into flame when held in the gas, thus showing the gas to be oxygen. This behavior lends support to the belief that the crystalline material in each case is an oxygen-deficient compound. Apparently, the atomic configuration assumed upon crystallization is incapable of accommodating all of the oxygen required for the formulas $Na_2O \cdot 3V_2O_5$ and $Na_2O \cdot 6V_2O_5$. However, when the crystallized samples are remelted, oxygen is reabsorbed from the atmosphere, only to be again expelled on recrystallization. This phenomenon has been noted previously by other workers.^{8,9} It is highly probable that the crystalline NV_6 mixture corresponds essentially to the compound $Na_2O \cdot V_2O_4 \cdot 5V_2O_5$, discovered by Canneri.¹⁸ The particular complex vanadate with which the solid NV_3 mixture is to be correlated is much less apparent.

Characteristics of the Phases

Sodium sulfate in its various polymorphic forms is well known both optically and by x-ray diffraction.^{20,21} The form encountered in this study appears to be largely Na_2SO_4 -III. The identity of $NaVO_3$ rested upon comparison with reference material known to be $NaVO_3$. In its occurrence in ashes C and A and certain other mixtures, it resembled the standard in exhibiting colorless laths and needles of high birefringence, parallel extinction, positive elongation, and refractive indices ranging from slightly below 1.80 to well above 1.88.

The V_2O_5 -like phase observed in ash B, and the phase believed to correspond with the complex vanadate, $Na_2O \cdot V_2O_4 \cdot 5V_2O_5$, both resemble V_2O_5 in being deeply-colored, pleochroic, highly-birefringent, and displaying extremely high refractive indices. A noticeable difference exists between these deeply-colored phases as regards the streak obtained on an unglazed porcelain test-plate; the streaks of fused NV_3 , NV_6 and V_2O_5 are, respectively, reddish-brown, very dark-brown and yellow-brown. Similar color differences can be detected microscopically.

X-ray powder patterns were obtained on all of the

⁽²⁾ Supplied by the Vanadium Corporation of America, Cambridge, Ohio.

mixtures listed in Tables 1, 2, and 3, using chromium radiation and a vanadium filter. In Table 5 the data for ashes A, B, and C are compared with those for the various compounds procured for reference standards. The only phases detected in these ashes were Na_2SO_4 , NaVO_3 , and the NV_3 -complex. In the more extended series of Na_2SO_4 - V_2O_5 mixtures, the same three phases were encountered, with the two additional phases, $\text{Na}_2\text{O} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5$ and V_2O_5 , making their appearance in the mixtures of high- V_2O_5 content. No indication whatsoever was found for Na_3VO_4 , $\text{Na}_4\text{V}_2\text{O}_7$, or any possible Na_2SO_4 : V_2O_5 additive compounds. Table 6 summarizes the results on these additional mixtures.

Selection of the Pertinent Compatibility Diagram

It is now possible to choose between the four diagrams presented as theoretical possibilities in Figure 1. The volatilization and phase identification studies definitely rule out diagrams (a), (c) and (d). Any modifications of (a) that would involve the formation of additive compounds between Na_2SO_4 and V_2O_5 also are eliminated. Only diagram (b) is at all compatible with the evidence, and even this requires modification because of the occurrence of the two complex vanadates. Strictly speaking, the latter do not fall on the triangle Na_2O - SO_3 - V_2O_5 , because they are only slightly so, and since on melting they apparently absorb the oxygen necessary to bring them to the Na_2O - V_2O_5 edge of the triangle, it does not seem amiss to represent them by such approximate formulas as $\text{Na}_2\text{O} \cdot 3\text{V}_2\text{O}_5$ and $\text{Na}_2\text{O} \cdot 6\text{V}_2\text{O}_5$. By joining the latter points to the SO_3 apex the compatibility relations are complete. The modified version of Figure 1 (b) is shown in Figure 3.

The foregoing relationships clearly demonstrate that the simplified picture of Na_2SO_4 - V_2O_5 ashes held by previous investigators is untenable. Figure 3 indicates that heat-treated compositions in this series can no longer be regarded as mere mechanical mixtures or simple solutions of Na_2SO_4 and V_2O_5 . Nor is there justification for postulating the formation of such additive compounds as $\text{Na}_2\text{SO}_4 \cdot 2\text{V}_2\text{O}_5$ or $\text{Na}_2\text{SO}_4 \cdot 9\text{V}_2\text{O}_5$. The more plausible interpretation of the Na_2SO_4 - V_2O_5 ashes which has emerged from the present studies and which is implicit in Figure 3, may be summarized as follows:

1. Na_2SO_4 exists only in mixtures containing less than 56 percent V_2O_5 .
2. SO_3 is liberated from all mixtures, partially up to 56 percent V_2O_5 (at which the weight loss reaches a maximum of 24.5 percent), and completely beyond 56 percent V_2O_5 .
3. The 56 percent V_2O_5 mixture consists entirely of NaVO_3 .
4. The 80 percent V_2O_5 mixture consists entirely of the NV_3 -complex.

N = Na_2O V = V_2O_5 S = SO_3

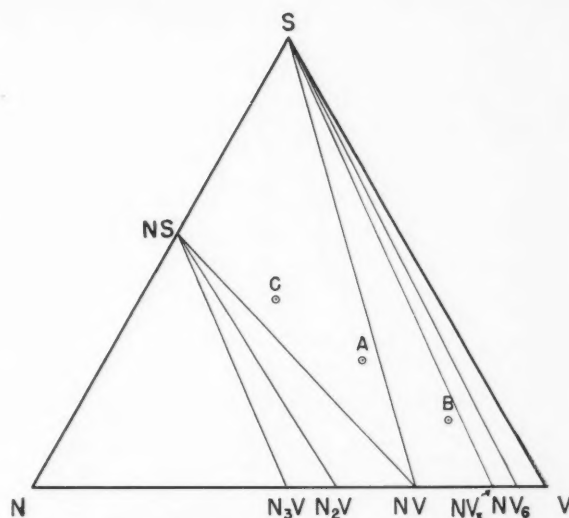


Figure 3—Compatibility relations in the System Na_2O - SO_3 - V_2O_5 , showing synthetic ashes A, B and C.

TABLE 4—Phases Present in Synthetic Ashes

ASH	MAJOR PHASES OBSERVED	
	Microscopic	X-ray Diffraction
C.....	Na_2SO_4 ; NaVO_3	Na_2SO_4 ; NaVO_3
A.....	NaVO_3 ; Na_2SO_4 (minor)	NaVO_3 ; Na_2SO_4 (minor)
B.....	V_2O_5 like phase; NaVO_3 (minor)	Unidentified phase; NaVO_3 (trace)

5. The 88.8 percent V_2O_5 mixture consists entirely of the complex, $\text{Na}_2\text{O} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5$.
6. Free V_2O_5 exists only in mixtures containing in excess of 88.8 percent V_2O_5 .

Significance in Corrosion Studies

Possible Agents of Corrosion

The chemical entities which suggest themselves as possible corrosion agents in Na_2SO_4 - V_2O_5 ashes on the basis of the newly acquired data are Na_2SO_4 , SO_3 , NaVO_3 , the NV_3 -complex, $\text{Na}_2\text{O} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5$, and V_2O_5 . Not all of these would be operative in any one selected ash (Figure 3). For all members except the Na_2SO_4 and V_2O_5 end-members, SO_3 (or strictly speaking, the equilibrium mixture of SO_3 , SO_2 , and O_2 appropriate for the temperature under consideration) is present and available as a possible corrodent. The particular compound or compounds which accompany the SO_3 depend, of course, on the mixture being considered. At certain critical compositions only one additional phase, NaVO_3 , the NV_3 -complex, or $\text{Na}_2\text{O} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5$, will be present; otherwise there will be a mixture of two. Only toward the V_2O_5 end of the series could V_2O_5 as such function as a corrodent. In addition to O_2 involved in the

TABLE 5—X-Ray Diffraction Data

Na ₂ SO ₄		Ash C		Ash A		NaVO ₃		Ash B		"NV ₃ "		"NV ₆ "		V ₂ O ₅		Na ₃ VO ₄	
d*	I**	d	I	d	I	d	I	d	I	d	I	d	I	d	I	d	I
												9.5	5	11.2	1		
								7.1	2	7.2	4	7.4	3	10.7	1	7.7	3
				6.9	1	7.0	1					7.2	9				
								6.8	10	6.8	10	6.8	2				
								5.8	1	5.8	1			5.8	1	6.6	5
								5.2	1	5.3	1			5.7	2	5.8	1
						5.0	1					4.95	1				
						4.95	1					4.7	5				
4.7	2	4.95	1	4.95	3	4.8	1							4.4	3	4.35	10
		4.7	1	4.7	2	4.7	2							4.3	10		
												4.05	1	4.1	1		
												3.85	4	4.05	6		
3.88	5	3.9	2	3.9	1			3.85	1	3.85	2					3.75	1
3.72	5	3.8	1	3.75	1			3.62	1	3.63	1						
												3.60	4	3.60	1	3.58	5
3.50	1	3.59	1	3.60	4	3.60	3					3.47	3	3.45	1		
3.45	3	3.48	3	3.45	1	3.50	1	3.46	2	3.45	5						
		3.45	1					3.43	1					3.37	7	3.37	4
				3.41	2	3.40	3										
																3.3	3
3.18	1	3.25	3	3.25	10	3.24	10	3.24	1	3.18	5	3.18	1			3.13	3
		3.17	1	3.17	1	3.17	1	3.18	5			3.15	1			3.10	3
3.07	1	3.13	1	3.13	8	3.13	10	3.08	1	3.08	2						
		3.08	1														
						2.99	1	3.00	6	3.00	7	3.05	10			2.98	2
						2.93	2	2.98	1	2.98	1	2.99	1			2.93	1
												2.92	5	2.86	8	2.88	2
												2.89	1				
																2.83	10
2.80	10	2.80	10	2.80	4	2.77	2	2.77	1					2.75	3	2.75	2
		2.77	1	2.77	3	2.75	1							2.67	1	2.67	4
				2.75	1							2.72	4				
		2.67	1	2.67	4	2.67	5										
2.62	7	2.63	4	2.63	3			2.63	1	2.63	1	2.62	1	2.60	2	2.60	3
												2.60	3	2.52		2.52	1
2.43	1			2.43	1	2.44	1	2.41	1	2.41	1	2.45	1			2.41	2
						2.41	1										
2.36	6	2.37	2	2.37	2			2.31	1	2.32	2	2.38	2	2.38	1	2.38	2
		2.29	1	2.30	2	2.29	4	2.27	1	2.27	1					2.32	1
								2.26	3	2.26	5						
2.23	1	2.24	1	2.25	1	2.25	1							2.23	1	2.22	3
2.17	1	2.17	1	2.17	2	2.17	3					2.18	10	2.17	8	2.17	1
2.13	1	2.13	1	2.13	1							2.13	1	2.14	3	2.15	1
2.08	1	2.09	2	2.09	2	2.09	1									2.09	2
2.07	1	2.08	1									2.07	1				
2.05	1	2.06	1	2.06	1	2.06	1	2.02	1	2.02	1	2.05	1	2.04	1	2.03	1
												2.02	1				
1.95	6	1.96	4	1.96	3	1.96	4	1.97	1	1.96	2	1.98	5	1.98	1		
								1.96	1	1.95	1						
1.88	3	1.88	2	1.88	1	1.91	1					1.93	1	1.92	4		
						1.88	1					1.92	1	1.89	3		
1.86	1	1.86	1	1.86	2	1.86	2	1.82	1	1.82	1	1.87	3	1.86	1	1.84	2
						1.82	1	1.80	4	1.80	4	1.82	1	1.83	1	1.81	1
		1.80	2	1.81	1	1.80	1					1.80	4			1.78	4
								1.76	1	1.76	1	1.76	1	1.78	2	1.75	1
1.74	6	1.75	1	1.75	2	1.75	3	1.74	1	1.74	1			1.75	3	1.75	1
		1.74	6	1.74	1	1.73	1							1.74	1	1.74	1
1.69	1			1.72	1	1.72	1	1.72	2	1.71	2	1.69	1			1.73	1
				1.69	1	1.69	1					1.67	2			1.66	1
				1.67	1	1.67	1					1.65	1	1.65	1	1.65	1
1.62	2	1.62	1	1.65	1	1.65	1	1.59	1	1.59	1					1.60	1
						1.62	1									1.59	1
						1.59	1										
1.58	4	1.58	2	1.58	1	1.58	2					1.58	3	1.57	1	1.57	1
1.56	4	1.56	2	1.56	1			1.55	1	1.55	1	1.55	1	1.56	1		
												1.54	1	1.54	1	1.54	1
1.53	2	1.535	1	1.535	1							1.53	1	1.52	1	1.53	1
		1.525	1	1.525	1							1.52	1				
		1.51	2	1.51	6	1.51	6	1.51	1	1.51	1						
								1.505	1	1.505	1						
1.48	1	1.48	1									1.49	4	1.49	3	1.48	1
												1.48	1				
1.46	4	1.46	3	1.46	3	1.46	2	1.46	1	1.46	1	1.46	1				

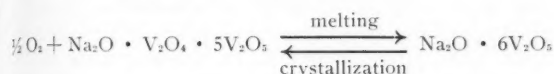
TABLE 5 (Continued)

Na ₂ VO ₄		Na ₂ SO ₄		Ash C		Ash A		NaVO ₃		Ash B		"NV ₃ "		"NV ₆ "		V ₂ O ₅		Na ₂ VO ₄	
d	I	d*	I**	d	I	d	I	d	I	d	I	d	I	d	I	d	I	d	I
1.44	1					1.41	2	1.41	1	1.45	1	1.45	1	1.45	1	1.44	4	1.45	1
										1.42	1	1.425	1					1.43	1
1.395	4									1.41	1	1.41	1	1.40	1	1.41	1	1.415	1
1.37	2	1.38	1	1.38	1	1.37	2	1.385	1					1.39	4	1.38	1	1.375	1
		1.37	1					1.375	2					1.37	1			1.37	1
						1.36	1	1.36	1	1.35	1	1.35	1			1.36	2	1.36	1
																1.345	1	1.35	1
1.32	1	1.33	1	1.33	2	1.33	2	1.33	2	1.33	2	1.33	3	1.33	3	1.335	1	1.34	2
1.295	3	1.295	1	1.29	1	1.29	1	1.29	1					1.30	2	1.315	1	1.32	1
																1.295	1		
1.27	1													1.28	1			1.28	1
1.25	1	1.255	1					1.255	1					1.275	1	1.27	3	1.27	1
1.235	2	1.235	1											1.255	1				
														1.24	1				
														1.23	3				
1.21	1													1.225	1				

* d = Interplanar spacing in Angstrom units.

** I = Line-intensity (visually estimated).

SO₃-SO₂-O₂ equilibrium and O₂ from the atmosphere, O (possibly of the nascent type) might be expected to arise through a mechanism such as:



It is apparent from these considerations that the process of corrosion must be one of considerable complexity.

Validity of These Relations for Molten Mixtures

Investigators of the oil-ash corrosion problem are in agreement in insisting that appreciable corrosion occurs only when the ash is wholly or largely molten. In the present study, the temperature used (1600 F) is such as to ensure complete melting for all members of the Na₂SO₄-V₂O₅ series. The objection might be raised therefore that compatibility relations found to exist between the crystalline compounds are not necessarily valid for completely molten materials. Such an objection might not readily be refuted to the complete satisfaction of all. Attempts to do so would necessarily involve consideration of the structure of liquid solutions, a subject fraught with considerable controversy. However, there seems to be satisfactory evidence that molten Na₂SO₄, for example, does not behave in corrosion studies as if it were merely a solution of SO₃ in molten Na₂O, nor does molten NaVO₃ behave as if it were merely a solution of Na₂O in molten V₂O₅. Rather they behave as if the molten material substantially retained the types of linkage and coordinations present in the corresponding crystalline compounds. On this basis, structure differences between a particular molten composition and the corresponding crystalline compound or mixture of compounds are believed to be differences of degree rather than of kind. In this connection it should be emphasized that the valid consideration of at least one of the chemical entities listed (SO₃) as a possible corrodent is completely independent of any theory for the structure of the molten mixture.

TABLE 6—Phases Present in Additional Mixtures

Composition of Original Mixture, Wt. %			Phases Revealed by X-ray Diffraction
Na ₂ SO ₄	Na ₂ O	V ₂ O ₅	
70	....	30	Na ₂ SO ₄ ; NaVO ₃
60	....	40	NaVO ₃ ; Na ₂ SO ₄
40	....	60	NaVO ₃ ; NV ₃
30	....	70	NV ₃ ; NaVO ₃
20	....	80	NV ₃
18	....	82	NV ₃ ; NV ₆
16	....	84	NV ₃ ; NV ₆
14	....	86	NV ₆ ; NV ₃
11.2	....	88.8	NV ₆
10	....	90	NV ₆ ; V ₂ O ₅ (?)
5	....	95	NV ₆ ; V ₂ O ₅
3	....	97	NV ₆ ; V ₂ O ₅
1	....	99	V ₂ O ₅ ; NV ₆
....	14.5	85.5	NV ₃ ; NaVO ₃
....	12.0	88.0	NV ₃ ; NaVO ₃
....	10.2	89.8	NV ₃
....	7.8	92.2	NV ₃ ; NV ₆
....	6.4	93.6	NV ₆ ; NV ₃
....	5.3	94.7	NV ₆

Correlation with Some Previous Investigations

Although references to "V₂O₅-corrosion" by oil-ash residues are frequent, at least several workers have indicated on the basis of x-ray diffraction study that V₂O₅ as such may seldom be present.^{7, 22} Results of the present study are in accord with such a belief. Only those Na₂SO₄-V₂O₅ mixtures containing in excess of 88.8 percent V₂O₅ would be expected to contain free V₂O₅.

There has been occasional mention of Na₂O·V₂O₄·5V₂O₅ as an ash constituent and possible corrodent,^{2, 8, 23} but in the main this phase has been overlooked in Na₂SO₄-V₂O₅ studies. It is interesting that in at least four previous studies^{10, 11, 12, 24} the most corrosive Na₂SO₄-V₂O₅ mixture was very close to that composition (12 Na₂SO₄-88 V₂O₅) which has been found to yield Na₂O·V₂O₄·5V₂O₅ after expulsion of SO₃ and O₂. The high corrosivity of this complex vanadate also has been noted in this investigation. Judging by the behavior of ash B, the NV₃-complex is also highly corrosive.

In general, investigators of synthetic Na₂SO₄-V₂O₅ ashes have not invoked the sodium vanadates as possible corroding agents. It must be noted, however, that a number of students of the oil-ash corrosion problem have listed all three sodium vanadates as

potential agents.^{3,9,23} The present study singles out NaVO_3 as the only one of the three vanadates which might be involved in corrosion. It will be recalled that no indication of the presence of either $\text{Na}_4\text{V}_2\text{O}_7$ or Na_3VO_4 was found in heat-treated $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures. Even in actual ashes encountered in practice it appears that the $\text{Na}_2\text{O}:\text{SO}_3:\text{V}_2\text{O}_5$ ratios are in many cases such as to exclude the possibility of simple vanadates other than NaVO_3 being present. It is of interest that in a few corrosion experiments conducted by the authors in pure molten NaVO_3 , the corrosive attack by the latter was extremely mild, and not at all what one would expect if this compound dissociated on melting to liberate its 74.6 percent V_2O_5 as free vanadium pentoxide. Accordingly, it is believed that molten NaVO_3 retains linkages characteristic of the crystalline compound.

The literature on corrosion by fuel oil residues is by no means lacking in references to the role of sulphur trioxide.^{25,26} Such references, however, are concerned in general with low-temperature corrosion rather than that at temperatures in the 1300-1700 F range of interest in the present discussion.

Little more than incidental mention has been made of the possible role of SO_3 in high temperature corrosion. In $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ ash studies, at least, the possibility that SO_3 might be substantially liberated by interaction between the end-members apparently had been overlooked previously. The present study indicates that SO_3 probably plays a much more important role in high temperature corrosion than previously suggested.

It has been stated that the quantity of SO_2 and SO_3 present in the gas stream of the gas turbine is many times that required to convert all the metal oxides in the fuel to sulfites and sulfates.²³ In one reported study of corrosion of heat-resisting steel samples, SO_2 was found to be 15 times as corrosive as air,²⁷ and it is believed that SO_3 would be more active than SO_2 in attack on metals at high temperatures.⁹ Data on the $\text{SO}_3\text{-SO}_2\text{-O}_2$ equilibrium would indicate that SO_2 should constitute about 75 percent of the equilibrium mixture at 1600 F.²⁸ The well-known catalytic effect of V_2O_5 is believed to operate in the case of vanadium-containing oil-ash residues to accelerate establishment of the equilibrium in favor of SO_3 .²⁹

In the present investigation preliminary tests were conducted to determine qualitatively the possible corrosive strength of SO_3 on specimens of Inconel X and 310 stainless steel. In one test the action of a prefused $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixture was compared to that of the same mixture which had not been preheated. In the former, of course, the SO_3 has been evolved prior to the test, whereas in the latter the SO_3 was evolved during the corrosion experiment. In another test the specimen was placed above and out of contact with the molten mixture, in the path of the escaping SO_3 . Both types of test demonstrated the strong corrosive action of SO_3 on such materials. Further work in this direction is contemplated.

Students of the oil-ash corrosion problem seem agreed that Na_2SO_4 is one of the potential corroding

agents both in synthetic $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ ashes, and in the more complex ashes encountered in actual turbine practice. In a number of instances this compound has been identified as a constituent of gas turbine deposits.^{7,23,30} The thermal stability of Na_2SO_4 is high, there being little tendency to dissociate at temperatures as high as 2550 F.²⁵ The present study leaves little doubt that Na_2SO_4 as such is present in all $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures containing not more than 56 percent V_2O_5 .

Study of a wide variety of specimens indicates that Na_2SO_4 varies widely in its corrosivity. For example, in 24 hours exposure, at 1600 F, 310 stainless steel was practically unaffected, whereas Inconel X was heavily attacked. The presence of substantial carbon in the test medium of Na_2SO_4 has been shown to greatly enhance its corrosiveness.¹⁰ However, carbon cannot be assigned a universal effect, good or bad, for the presence of small amounts of carbon in $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ synthetic ashes high in Na_2SO_4 have been found by the authors to suppress markedly the corrosiveness of these ashes on Inconel X. A slag-line type of attack is observed in either case, presumably associated with the evolution of SO_3 . The beneficial effect of carbon, where observed, may involve driving the reaction $\text{SO}_3 + \text{C} \rightleftharpoons \text{SO}_2 + \text{CO}$ to the right, eliminating SO_3 as an oxygen source (i.e., $\text{SO}_3 \rightleftharpoons \text{SO}_2 + 1/2 \text{O}_2$). This tentative explanation is consistent with the opinion that burning residual fuels under reducing conditions minimizes corrosion.

It is generally conceded that oil-ash corrosion of metallic materials is essentially an accelerated oxidation phenomenon. In attempting to name the culprits, one must not minimize the role of oxygen as the ultimate corroding agent. Oxygen, of course, is an ever-present constituent in the combustion atmosphere. Far more important, however, may be the oxygen made available through the $\text{SO}_3\text{-SO}_2$ exchange mechanism, and the peculiar behavior of the NV_3 -complex and of $\text{Na}_2\text{O} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5$ on passing through their melting points. Such oxygen is probably of the nascent type, and presumably highly reactive. It is not unlikely that any and all of the corrosive agents discussed above are corrosive primarily because of such reversible reactions. In other words, they serve as oxygen-carriers, their capabilities in this regard being related to the facility with which their sulfur or vanadium ions can change from one valence state to another.

Applicability of Equilibrium Relations to High-Temperature Corrosion

The compatibility relations depicted and discussed in earlier sections admittedly apply to equilibrium conditions, or at least conditions which do not depart widely therefrom. There can be little doubt that near-equilibrium obtains in the $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures used in the 24 hour corrosion tests at 1600 F. The question naturally arises: How closely might the oil-ash residues which accumulate in gas turbine operation be expected to approach equilibrium. Changes in conditions of operation, in fuel source, etc., might

and in equal turn is composed of gas Na_2SO_4 which dissociate at study present in more than tes that example, ss steel X was carbon down to carbon or bad, carbon in O_4 have edly the A slag-presum- bene- involve to the ce (i.e., ation is residual rrosion. osion of d oxid- culprits, the ulti- an ever- osphere. oxygen e mech- complex gh their the nas- t is not ents dis- of such erve as regard r sulfur ce state

easily lead to variation in the composition of the accumulating deposits. Corrosion reaction with the underlying metal parts is bound to modify the composition of the corroding ash. Such factors tend to promote non-uniformity in the ash. Other factors, however, tend to work in the opposite direction. In view of the very low percentage of inorganic constituents in residual fuel oils, combustion of the latter must lead to a very slow accumulation of the deposits. Add to this the fact that the deposits are largely if not wholly molten under high temperature operating conditions and it would appear that the likelihood of near-equilibrium is strong. X-ray identification studies of actual deposits, limited though they have been, serve to bear out the contention that equilibrium considerations provide a reasonable approximation to the conditions prevailing in the molten ash residues.

Conclusion

In this paper an attempt has been made to demonstrate the utility of phase equilibrium principles in the consideration of a complex practical problem: residual oil-ash corrosion. Its intent has been to provide a sound and simple datum plane for corrosion experiments, rather than to record a host of observations on specific corrosion tests. Admittedly, the approach used has been elementary. No attempt has been made to arrive at a full-fledged phase equilibrium diagram, nor is such a diagram regarded as necessary for the purpose in hand. It is believed that those relationships of the system $\text{Na}_2\text{O}-\text{SO}_3-\text{V}_2\text{O}_5$ essential to a better understanding of the role of sodium, sulfur and vanadium in corrosion have been satisfactorily established.

The compatibility diagram deduced from these studies has been utilized as a background for the consideration of the role of $\text{Na}_2\text{SO}_4-\text{V}_2\text{O}_5$ ashes in corrosion. The work of the present as well as of previous investigators has been analyzed in the light of this diagram. As was anticipated, this approach has led to considerable clarification of the role of $\text{Na}_2\text{SO}_4-\text{V}_2\text{O}_5$ mixtures in corrosion. A number of apparent conflicts have been resolved and co-ordinated into one over-all pattern.

It has been possible to establish the following compounds as participating more or less actively in corrosion: Na_2SO_4 , SO_3 (including SO_2 and O_2), NaVO_3 , the NV_3 -complex, $\text{Na}_2\text{O} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5$, nascent O_2 , and in extreme cases, V_2O_5 . Furthermore, it becomes possible to decide which members of this group are involved for any selected $\text{Na}_2\text{SO}_4-\text{V}_2\text{O}_5$ mixtures.

The perplexing observation that certain intermediate compositions are more corrosive than either Na_2SO_4 or V_2O_5 alone has been accounted for on the basis of the peculiar behavior of the NV_3 -complex and of $\text{Na}_2\text{O} \cdot \text{V}_2\text{O}_4 \cdot 5\text{V}_2\text{O}_5$. The need for greater attention to the possible role of SO_3 in high temperature corrosion has been pin-pointed. Compounds of such postulated formula as $\text{Na}_2\text{SO}_4 \cdot 9\text{V}_2\text{O}_5$, etc., have been discredited. Sodium vanadates corresponding to the formulas Na_3VO_4 and $\text{Na}_4\text{V}_2\text{O}_7$ have been elim-

inated from consideration. Phase identification by both X-ray diffraction and optical means have provided adequate reference data for additional studies of oil-ash residues, whether actual or synthetic.

It is believed that the results and the application of principles presented herein constitute a useful framework for further studies and interpretations pertaining to oil ash corrosion.

Acknowledgment

This paper is the outgrowth of a protective coating development supported by the Department of the Navy, Bureau of Ships under contract NObS-62161, with Forrest R. Nagley and David E. Garen as supervisory technologists of the sponsoring agency. The research was conducted under J. O. Everhart, Supervisor of Ceramic Research.

References

1. H. R. Cox. Industrial Gas Turbines. *J. Inst. Metals*, **77**, 287-307 (1950).
2. E. L. Bass, I. Lubbock, and C. G. Williams. The Gas Turbine and Its Fuels. *Shell Aviation News*, No. 156, June, 1951.
3. P. Draper. The Use of Residual Fuel Oils in Gas Turbines. Paper No. 52-A-127, ASME Annual Meeting, New York, Nov.-Dec., 1952.
4. A. A. Hafer. Gas-Turbine Progress Report—Materials, Cooling and Fuels. *Trans. ASME*, **75**, 127-136 (1953).
5. W. A. Lambertson. A Study of a Slagged High-Alumina Firebrick from a Naval Boiler. *Bull. Am. Ceram. Soc.*, **28** [7] 260-266 (1949).
6. W. C. Bell, J. R. Hart, and I. W. Gower. Slagging of Navy Boiler Refractories. *N. C. State College Engrg. School Bull.*, No. 58, 46 pp., July, 1953.
7. J. B. McIlroy, E. J. Holler, Jr., and R. B. Lee. The Application of Additives to Fuel Oil and Their Use in Steam-Generating Units. *Trans. ASME*, **76**, 31-46 (1954).
8. P. Schapfer, P. Amgwerd, and H. Preis. Attack on Heat-Resistant Steels of Vanadium-Containing Oil-Ashes. *Schweiz. Archiv fur Wissenschaft. Tech.*, **15**, 291-299 (1949).
9. C. T. Evans, Jr. Oil Ash Corrosion of Materials at Elevated Temperatures, ASTM Spec. Publ. No. 108, 59-105 (1950).
10. B. O. Buckland, C. M. Gardiner, and D. G. Sanders. Residual Fuel-Oil Ash Corrosion. Paper No. 52-A-161, ASME Meeting, New York, Nov.-Dec., 1952.
11. F. C. Monkman and N. J. Grant. An Investigation of Accelerated Corrosion of Heat Resistant Metals Due to Vanadium. *Corrosion*, **9**, 460-466 (1953).
12. G. W. Cunningham and A. deS. Brasunas. Accelerated Oxidation of High Temperature Alloys as Influenced by Contamination with Sodium Compounds and Certain Fuel Oil Ash Components. Final and Summary Report, Dept. of the Navy, Contract No. NObS-65576, May 30, 1955.
13. E. G. Stevens, M. Leipold, and T. S. Shevlin. Cermet Coating Development, Quarterly Summary Report No. 19, Dept. of the Navy, Contract No. NObS-62161, Jan. 31, 1955.
14. Analysis of "Fireside Deposit." Furnished by U. S. Naval Boiler and Turbine Laboratory, Philadelphia, Pa.
15. C. Sykes and H. T. Shirley. Scaling of Heat-Resisting Steels. Influence of Combustible Sulphur and Oil-Fuel Ash Constituents. Iron & Steel Inst. Spec. Report No. 43, 153-169 (1952).
16. W. R. Foster. Solid State Reactions in Phase Equilibrium Research. *Bull. Am. Ceram. Soc.*, **30** [8] 267-270, [9] 291-296 (1951).
17. W. R. Foster. A Study of Solid-State Reaction in the Ternary System $\text{MgO}-\text{ZrO}_2-\text{SiO}_2$. *J. Am. Ceram. Soc.*, **34** [10] 302-305 (1951).
18. G. Canneri. Sui vanadicovanadati. *Gazzetta Chimica Italiana*, **58**, 6-25 (1928).
19. B. W. King and L. L. Suber. Some properties of the oxides of vanadium and their compounds. *J. Amer. Ceram. Soc.*, **38** [9] 306-311 (1955).

20. A. N. Winchell. The Microscopic Characters of Artificial Inorganic Solid Substances or Artificial Minerals, 2nd Edition, John Wiley & Sons, Inc., 403 pp. (1931); p. 216.
21. A.S.T.M. Card File of X-ray Diffraction Data, Card 1-1000.
22. C. T. Evans, Jr. Discussion of Group Papers. Iron & Steel Inst. Spec. Rpt. No. 43, 356-359 (1952).
23. A. T. Bowden, P. Draper, and H. Rowling. The Problem of Fuel-ash Decomposition in Open-cycle Gas Turbines. Proc. Inst. Mech. Eng., **167**, 291-312 (1953).
24. S. H. Frederick and T. F. Eden. Corrosion Aspects of the Vanadium Problem in Gas Turbines. *Corrosion*, **11**, 35 (1955).
25. R. C. Corey, B. J. Cross and W. T. Reid. External Corrosion of Furnace-wall-tubes-II Significance of Sulphate Deposits and Sulphur Trioxide in Corrosion Mechanism. *Trans. ASME*, **67**, 289-302 (1945).
26. E. C. Hulse and E. C. Piottter. The Use of Additives for the Prevention of Low-temperature Corrosion in Oil-fired Steam-generating Units. *Trans. ASME*, **76**, 267-278 (1955).
27. D. A. Oliver and G. T. Harris. Some Proven Gas-Turbine Steels and Related Developments. Iron & Steel Inst. Spec. Rpt. No. 43, 46-59 (1952).
28. W. G. Rice-Jones. Sulfur in Ores, Concentrates and Other Metallurgical Samples. *Analytical Chem.*, **25** [9] 1383-1385 (1953).
29. W. Sacks. Properties of Residual Fuel Oils. Paper 53-F-1, Fall Meeting Fuel Division ASME, Rochester, N. Y., Oct. 1953, 5 pp.
30. A. M. Hall, B. Douglas, and J. H. Jackson. Corrosion of Mercury-Boiler Tubes during Combustion of a Heavy Residual Oil. *Trans. ASME*, **75**, 1037-1049 (1953).

**Any discussion of this article not published above
will appear in the December, 1956 Issue.**

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in *Corrosion* will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of *Corrosion* and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of *Corrosion*, 1061 M & M Bldg., Houston 2, Texas.

Magnetic Amplifier Type Recording Instrument For Electrolysis Survey*

By MICHIO TANAKA, JIRO YAMAGUCHI and YOSHIFUMI SAKURAI

Introduction

IN ORDER to make plans for corrosion control of underground metallic structures such as pipe lines and cables it is necessary to survey pipe line or cable sheath currents and pipe line or cable sheath to ground potentials. Such currents and potentials often are vigorously fluctuating and variable from time to time in the vicinity of electric railways according to the railway operating conditions. For this reason short duration measurements fail to give sufficient accounts of electrical conditions of those underground structures. Continuous 24-hour recording is desirable and usually sufficient. Those electrical quantities to be recorded in such surveys are usually so small that DC (or low frequency) amplifiers are required to operate conventional electrical recording meters. The combination of interrupter and electronic amplifier has been used hitherto, but it does not have sufficient stability and life. A recording instrument with magnetic amplifiers for the measurement of the above-mentioned purpose is described below.

Magnetic Amplifiers as Measuring Instruments

The amplifier should fulfill the following conditions in order for it to operate satisfactorily throughout the long duration of an electrolysis survey in the field:

1. It should be of rugged construction.
2. It should have large amplification for DC and low frequency (below 1 cps).
3. It should have small drift.
4. It should have low input impedance for the cable sheath current measurement and high input impedance for the cable sheath to ground potential measurement.
5. It should be usable with either power frequency AC or battery as the power source.
6. It should be usable with a conventional electrical recording meter.

The magnetic amplifiers of self-saturation type are suitable for this purpose.

The bridge-type circuit was selected and push-pull connection was used to eliminate the effect of voltage fluctuation in the power source. In order to satisfy condition No. 4, two windings were used (i.e., current and potential). The potential winding had an external resistor of about 10,000 ohms in series with it. In consideration of condition No. 5, the device includes an interrupter which converts the DC to AC.

Construction

Two magnetic amplifiers were constructed. The

*Submitted for publication January 24, 1955.

MICHIO TANAKA—Professor in charge of the power transmission and distribution course, Faculty of Science and Technology, Osaka City University, Osaka, Japan. Dr. Tanaka was engaged in power transmission and distribution engineering work with the Electric Bureau of Osaka City from 1926 to 1942 and with Kansai Power Company from 1942 to 1954. He received a Dr. (Eng.) degree from Kyoto University. He has been an active member of NACE since 1951 and a member of its Technical Committee T-4B since 1953.



JIRO YAMAGUCHI—Professor of electrical engineering, Osaka University, Osaka, Japan. He has been a member of the Kansai Electrolysis Control Committee since 1948 and is chairman of the electrolysis measurement committee. Dr. Yamaguchi's main research interests are in the field of electrical measurement, semi-conductor rectifiers and electrical machines. He received a Dr. (Eng.) degree from Kyoto University.



YOSHIFUMI SAKURAI—Assistant professor of electrical engineering, Osaka University, Osaka, Japan. Mr. Sakurai has done research involving the instrumental application of the magnetic amplifier since 1949 and is interested in electrical measurements in general. He is an active member of the Magnetic Amplifier Committee of the Institute of Electrical Engineers of Japan.

Abstract

In order to make plans for corrosion control of underground metallic structures it is necessary to survey the sheath current and potential against the ground. A current and voltage recording instrument which was designed for making an electrolysis survey is described and field tests results are reported. The instrument consists of a push-pull self-saturation type magnetic amplifier and a conventional electrical recording voltmeter. It was found to perform as follows:

1. For obtaining 0.6 volt (this corresponds to the full scale 50 mm in the recording meter used), input voltage of the amplifier with Mo-Permalloy cores was 0.48 millivolt for sheath current measurement and 740 millivolts for cable to ground potential measurement in case of the power source of 90 cps with rectangular wave form.

2. Response time was 7 cycles for current measurement and 4.5 cycles for voltage measurement.

3. When the source was supplied from the power line (60 cps), the amplification factors decreased about 10 to 35 percent.

The device had good stability, negligible drift and rugged construction. Therefore it is clear that this device is suitable for field test.

4.5.3

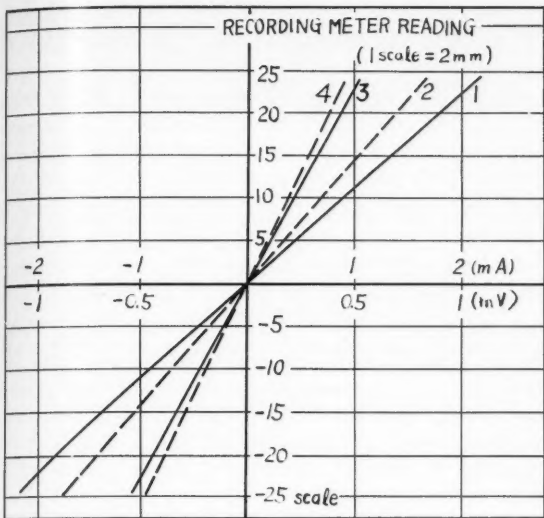


Figure 3—Amplification characteristics for sheath current measurement.

Amplifier 1 was 0.05 second and that of Amplifier 2 was 0.12 second. For the potential measurement this was 0.075 second. These values were satisfactory for the authors' use.

In the continuous operation of the magnetic amplifier for a long time, the variation of voltage source and drift are important factors which influence the stability. In the above mentioned magnetic amplifiers the change of amplification factor was below 1 percent and the change of zero point below 0.5 percent for 10 percent change of source voltage. The drift was negligible in continuous operation over a 48-hour period.

Field Test

Frequently these devices were tested in the field. The results are shown in Figures 5 and 6. Figure 5 shows the records of sheath current of a communication cable and Figure 6 that of the electric potential. The former was measured by Amplifier 1 and the latter by Amplifier 2. The potential drop between two points along the cable at 1 meter distance was amplified, so the sheath current was obtained by the following equation :

I = V / R

where :

- V = potential drop between two points along the cable
- I = sheath current
- R = resistance of the cable sheath per meter

If the resistance of lead wire from the cable to the amplifier were high compared with the internal resistance of the amplifier input winding, a correction would be required.

Considerations

Comparing Amplifier 1 with Amplifier 2, it is clear that the current amplification and the response time

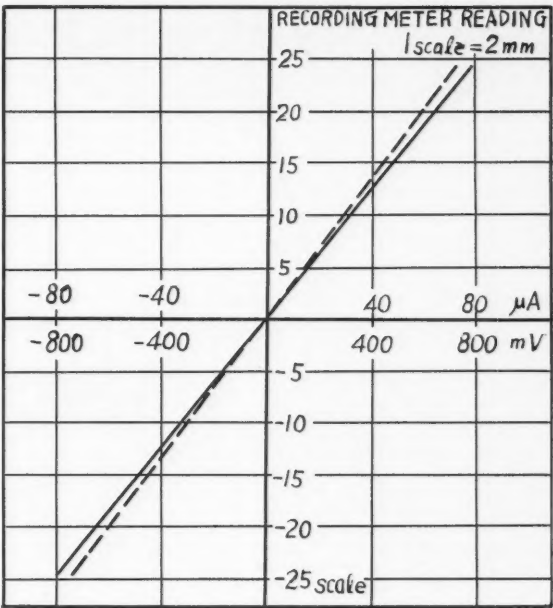


Figure 4—Amplification characteristics for cable potential measurement.

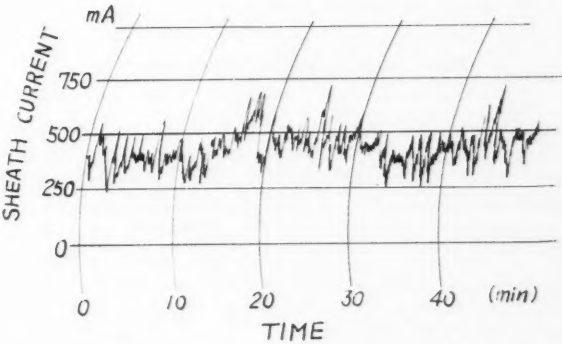


Figure 5—Record in sheath current measurement.

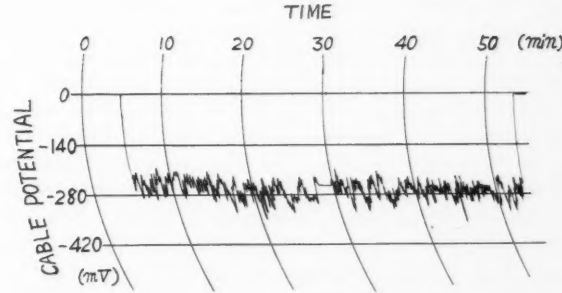


Figure 6—Record in cable potential measurement.

TABLE 3—Details of Power Transformer T-1

Part	Description
Core	T-class, Si-Steel, 0.35mm sheets, 3 legs, 82 x 70 x 25mm.
Windings	Primary winding: 130 turns 0.65mm enamel wire. Secondaries (Two identical): 185 turns 0.65mm enamel wire tapped at 65, 130, 165 turns.

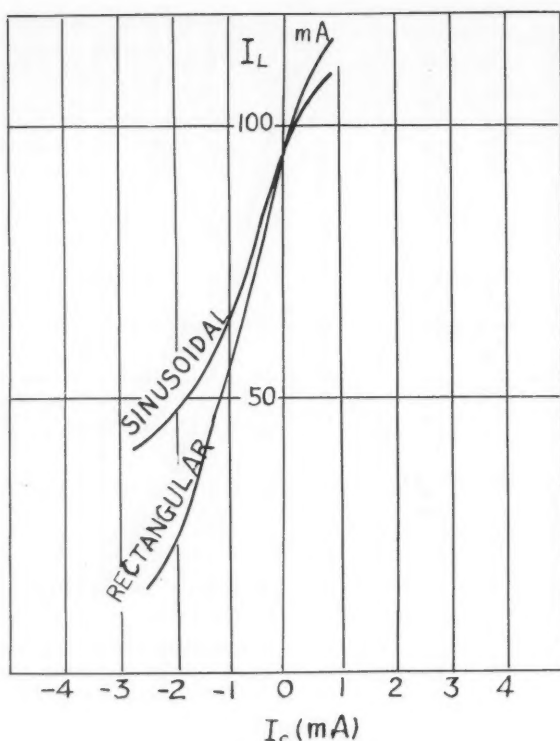


Figure 7—Effect of source voltage wave form.

of the former are about one-half of that of the latter. This is caused by the difference of the magnetization curve, because the dimensions of core and other constants are equal. In Mo-Permalloy the value of maximum permeability is about 50,000, while 50-Ni Permalloy has a round knee and higher saturation flux density. Amplifier 1 therefore has the capability of large output in spite of the poor amplification. Although the authors used "oriented-grain" ribbon cores in power amplifiers, they have not considered using them in an amplifier with such a small input for measurement purposes because a Permalloy core gives better performance than an oriented-grain core in such a small input amplifier.

It is evident from Figures 3 and 4 that when the

interrupter is used the sensitivity increases. This is caused by increasing the source frequency from 60 cps to 90 cps.

To study the effect of source voltage wave form, the amplification characteristics of single self-saturation magnetic amplifier were measured as shown in Figure 7. It follows that the linear portion of amplification characteristics is enlarged in the case of rectangular source voltage. The reason is as follows: Since the input impedance is low, the amplification characteristics forms the integral of the source voltage wave (i.e., cosine form for sine wave voltage while linear for rectangular wave voltage).

Conclusions

The performances of the current and voltage recording instrument for electrolysis surveys are as follows:

1. For obtaining 0.6 volt (this corresponds to the full scale 50 mm in the recording meter used in the experiment), input voltage of the Amplifier 2 is 0.48 millivolt for sheath current measurement and 740 millivolts for cable potential measurement in case of the power source of 90 cps with rectangular wave form.
2. Response time is 7 cycles for current measurement and 4.5 cycles for voltage measurement.
3. Using Amplifier 1, the amplification factor and response time is about one-half of the above mentioned values.
4. When the source is supplied from the power line (60 cps), the amplification factors decrease about 10 to 35 percent.

The device has good stability, negligible drift and rugged construction. From this it is clear that this device is suitable for field test work.

Acknowledgment

The authors express their thanks to the Kansai Electrolysis Control Committee for cooperation in field application of the instruments and to K. Shirae for his help in producing the amplifiers.

Any discussions of this article not published above will appear in the December, 1956 issue.

Potential Criteria for the Cathodic Protection Of Lead Cable Sheath*

By K. G. COMPTON

Introduction

FOR MANY years power and communications cables have been placed underground in direct contact with soil or soil waters. In many instances severe corrosion has destroyed the cable sheaths and caused interruption of service. In bygone years, the stray current from street railways was the principal source of trouble. This difficulty was overcome to a great extent by suitable bonding, return feeders and "forced drainage"⁽¹⁾ so that the cable system was at all times negative to the earth. More recently, protective coatings or wrappings have been applied to the cables, but they have not proved completely satisfactory because of holidays or weaknesses in the coatings. With the disappearance of the street railway, the fortuitous cathodic protection obtained through bonding and draining to the street railway has been lost and the incidence of corrosion leading to cable failures is rising.

Cathodic protection is the most practical means of alleviating the corrosion in existent underground plant. The criteria for cathodic protection of cable sheath are somewhat different from those for underground steel structures. Because of the extreme variability of the area of cable sheath in contact with soil or soil waters at any installation and the large shifts with time of the current density required to produce a given polarization, the use of current as the criterion is unsound. The potential of the polarized cable sheath as a half cell in the earth, using the copper sulfate reference electrode as the other half cell is a more practical criterion. Periodic and frequent adjustment of current to give the proper polarization potential where automatic devices are not available is the usual practice. In this paper data will be given that have led to this concept of the potential criteria for cathodic protection.

Potential Behavior of Lead

When bright lead is first placed in an aerated "neutral" solution such as soil water, local action processes cause a flow of metal ions into the solution



K. G. COMPTON—Has worked with corrosion problems for more than 25 years at the Bell Telephone Laboratories, Murray Hill, N. J. During World War II he was a consultant on the deterioration of materials to the NDRC and the Chief of Ordnance; he has also been active on corrosion committees of several technical societies. It was at the State College of Washington that he received his training in electrical and chemical engineering and in electrochemistry.

Abstract

A report is made of the study of the static and dynamic potentials of lead cable sheath in 48 soils from various sections of the United States. Soils have been selected as representative of those actually in contact with cable sheaths. Anodic and cathodic polarization curves in representative soils, using a null bridge technique, are given to illustrate the potential changes accompanying corrosion and cathodic protection. Data indicate that significant corrosion may occur at potentials near the static potential of the lead sheath for that particular soil. To achieve cathodic protection it appears that the lead sheath should be polarized about 100 millivolts more negative than its static potential in the particular soil. In most soils this would require polarization to about 700 millivolts negative to the saturated copper-copper sulfate electrode. 5.2.4

and a simultaneous increase in pH. A compound or solid phase is produced by combination of the lead ions with anions present in the soil water which initially provides for the least lead ion activity. The metal behaves as a Pb/Pb⁺⁺ electrode, the [Pb⁺⁺]_a being determined by the solubility product of the first formed compound. As lead ions are used up by precipitation new ones are taken into solution until at some final stage the lead acts as a lead-lead oxide electrode. Gatty and Spooner² show that if the single potential of lead is taken as -0.122 volt (H scale at 25 C) and the oxidation-reduction potential Pb⁺⁺/Pb⁺⁺⁺ as 1.75 volts, it may be calculated that for such an equilibrium:

$$\frac{[\text{Pb}^{++}]_a^2}{[\text{Pb}^{+++}]_a} = 10^{+62.5}$$

indicating that for all practical cases the proportion of Pb⁺⁺⁺ ions present is negligible.

The behavior of lead may be contrasted with that of copper where:

$$\frac{[\text{Cu}^+]^2}{[\text{Cu}^{++}]} = 10^{-4.3}$$

*Submitted for publication March 8, 1956. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.

⁽¹⁾ "Forced drainage" is a term that was coined by early electrolysis engineers to describe the method of forcing stray current to follow a desired path. It is separate and distinct from cathodic protection in which local corrosion cells are suppressed by polarization, through the deliberate application of current to a structure in an electrolyte. See the discussion by John M. Pearson, page 929 in the Corrosion Handbook, John Wiley & Sons, 1948. "Forced drainage" makes use of batteries, rectifiers or generators in a series circuit with the structure to direct the unwanted stray current to some other structure, such as a DC street railway system, or to a ground bed. In some fortuitous cases cathodic protection may be obtained at the point when the stray current is picked up.

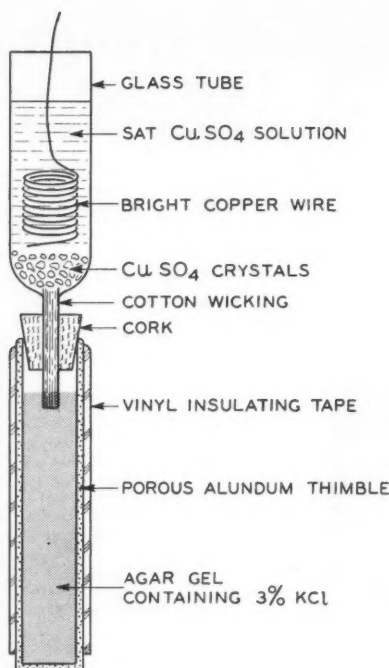


Figure 1—Saturated copper-copper sulfate reference electrode with agar salt bridge.

in which situation cupric ions predominate in solutions more concentrated than $10^{-4.3}$ M and cuprous ions in less concentrated solutions. In the case of lead, Gatty and Spooner state that the cathodic reaction is the reduction of O_2 molecules except in solutions of very low pH where consideration must be given to the discharge of H^+ ions. In the initial stages the surface of the lead consists of areas which are either base metal or "inhibitive" oxide film and the observed potential will be close to the static potential for a Pb/Pb^{++} electrode. After a considerable period, the surface of the metal will become filmed with a mixture of oxide and the solid compound produced by reaction of lead ions with anions in the soil water. According to Evans³ this film renders the cathodic portions of the metal "passive" and as the ratio of anodic areas to cathodic areas becomes vanishingly small, corrosion is effectively suppressed. The potential of the "passive" lead will be considerably more positive than that of bright metal or anodic lead.

Examples of the potential of lead in various electrolytes have been given by Gatty and Spooner.² For instance, they found that the potential of a freshly cut surface of lead was about -0.655 v to the saturated $Cu/CuSO_4$ electrode but reached a steady state potential of -0.569 v in 50 hours when immersed in 1.0 M KCl at 25 C. The steady state potential corresponds closely to the calculated potential for the electrode $Pb/PbCl_2/[Cl^-]_{a=1}$ of -0.578 volt. This would indicate that in this solution the lead electrode potential is controlled by the Cl^- concentration. This was verified when it was found that additions of solid $PbCl_2$ to the system had no effect on the potential when in this "first stage, steady state."

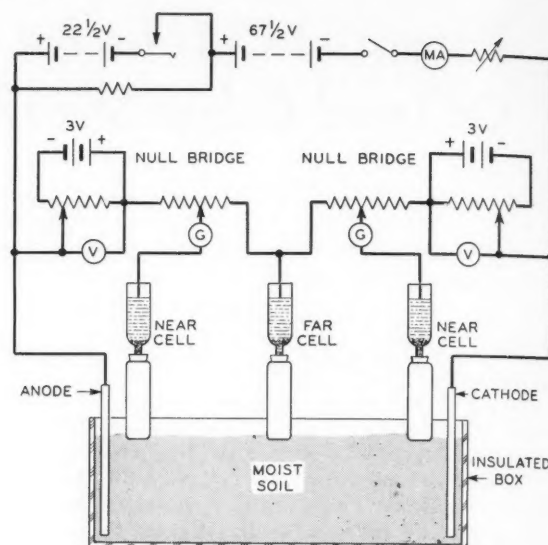


Figure 2—Assembly for making polarization measurements in soils.

TABLE 1—Effect of Gases on Steady State Potentials for Three Electrolytes

Electrolyte	H_2 Potential (In Volts)	N_2 Potential (In Volts)	O_2 Potential (In Volts)	Calculated Gas Free Basis
1.0 M HCl...	-0.594	-0.601	-0.576	-0.575
1.0 M KCl...	-0.635	-0.617	-0.580	-0.566
1.0 M KOH...	-0.936	-0.946	-0.889	-0.875

Other measurements in 1.0 M KNO_3 and in 0.5 M Na_2SO_4 gave "steady state" potentials of -0.606 v and -0.658 v respectively, to the copper sulfate electrode. The pH of the neutral 1.0 M KNO_3 rose to 9.3 by the time the "steady state" potential was reached. Measurements in pure water yielded a potential of -0.498 v. A calculated value for the electrode $Pb/Pb(OH)_2/[OH^-]_{a=1}$ is given as -0.886 .

Various gases were bubbled through solutions of three different electrolytes to determine the effect of hydrogen and oxygen upon the steady state potentials. Results are given in terms of the copper-copper sulfate electrode in Table 1.

Table 1 potential measurements were made in relatively pure and concentrated solutions, containing one major anion. Soil water is quite complex and variable in terms of the anions present, and may show a relatively low concentration of any ions. Furthermore, the effective viscosity of the soil, the degree of aeration, the pH and many other factors have a significant influence on the potential of lead in contact with it. In view of the lack of information in the literature and the need for it in connection with cathodic protection systems for underground cable, a study was made of the potential behavior of lead cable sheath in a variety of soils.

Sources of Soils

Soils were gathered by corrosion engineers of the Bell Telephone System from 48 different locations.

All were soils which would be in contact with lead cable sheath or would provide the ions in the soil water that would enter the ducts and manholes. These soils covered a wide range of both resistivity and pH; except for tidal marsh soil, they represent all unusual conditions any one engineer is likely to meet. No attempt was made to classify soils as to types as in the underground corrosion studies of the National Bureau of Standards.⁴

Experimental Methods

Three types of potential measurement were made: (1) the initial static potential upon contact of the freshly cut lead surface with the soil, (2) a static time-potential measurement, and (3) a dynamic measurement with current flowing, which provided anodic and cathodic polarization curves.

The 1 percent antimony alloy lead cable sheath specimens were cleaned by a combination of chemical dips and scratch brushing. The chemical dips were in hot 20 percent solution of ammonium acetate, in hot 1 percent acetic acid or in 10 percent fluoboric acid. The time in the chemical dips depended upon the amount of film on the specimens. It was found that the chemical dips were necessary for thick films as the scratch brushing tended to imbed particles of the film in the soft surface unless a very stiff coarse brush were used. The coarse brush was objectionable as it tended to roughen the surface excessively.

The soil was dried in an oven, pulverized and sieved through a standard 20 mesh screen. From the work of the Bureau of Standards⁴ it appears that the resistivity of a soil is essentially constant in the range of 40 to 75 percent moisture in terms of dry soil. All soils were adjusted to a stiff creamy texture within this range. In a few instances the soil would not take up 40 percent of water to give a smooth creamy consistency but tended to granulate and to settle out of the slurry into a dense layer. To avoid this stratification, resistivity measurements were made as quickly as possible using an M. C. Miller soil box and multi-combination meter. The pH measurements were made with the Beckman glass electrode pH meter on an extract of the soil obtained by shaking one volume of soil with four volumes of distilled water.

For the static measurements a group of ten lead-antimony cable sheath specimens, one inch wide and four inches long, were cleaned as described above. A copper-copper sulfate reference electrode, having a potassium chloride-agar salt bridge as shown in Figure 1, was placed in contact with the soil in a soil box. The cable sheath specimens were pushed into the soil and the potential to the reference electrode determined as quickly as possible. Measurements of all ten specimens were made in succession using a null slide-wire potentiometer. The measurements were repeated at ten minute intervals until the initial "steady state" developed or it became apparent that a long slow drift would be experienced.

In preparation for the dynamic measurements, two null bridges were set up, one for measuring the po-

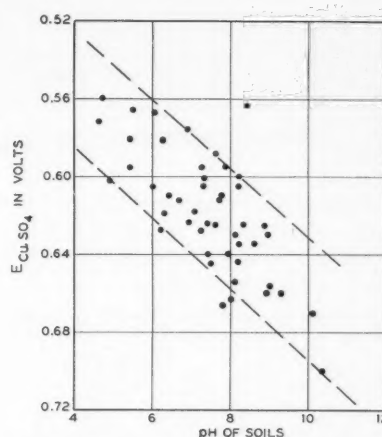


Figure 3—The initial potential of bright lead antimony cable sheath in various soils as a function of soil pH.

tential of the anode and the other for the cathode. This arrangement is shown in Figure 2. In the initial balancing of the bridges, brief pulses of current amounting to about 25 micro-amperes per square inch apparent current density were used. In most cases the specimens used for the anode and the cathode did not have identical potentials or were driven apart slightly by the effects produced by the balancing pulses.

After the bridges were balanced the initial zero current potential was determined. The current then was increased in steps at three minute intervals, beginning with a current density of .0025 ma/sq in. The current was doubled each time and potential measurements made at the end of the three minute intervals. The balance was checked frequently and rebalanced when necessary. As the current passed from the anode to the cathode, there was a migration of ions in both directions, a migration of water by electro-osmosis to the cathode, a decrease in pH at the anode and an increase in pH at the cathode. This necessitated rebalancing of the null bridges rather frequently in the later stages of the run. At some high current density the potentials would become unstable or the resistivity would become so high from electro-osmosis that current could not be forced through the cell at reasonable voltages and the run would be stopped.

Data

Using the technique described above, the resistivities, pH and the static potential of antimonial-lead cable sheath were measured in the 48 soils (collected from various underground cable sites). These data are given in Table 2. It will be noted that the pH of 15 of the soils was below 7, 10 between 6.5 and 7.5 and 33 above 7. Since roughly two-thirds of the soils are alkaline, the average potential of -0.617 volts may be slightly more negative than if a more representative group of soils proved to be of lower pH. It is interesting to note that a large majority of the soils were in the medium resistivity class (i.e., between 10 and

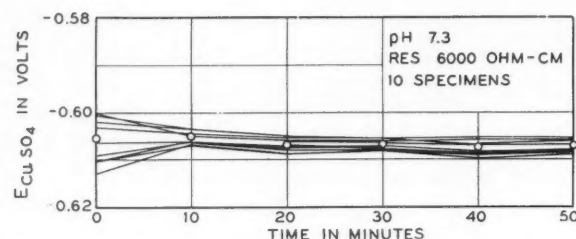


Figure 4—Time-potential curve of "bright" cable sheath in soil No. 33.

TABLE 2—Potential of Lead Cable Sheath in Various Soils

Location State	No.	Soil No.	pH	Resistivity (Ohm cm)	Potential Volts (CuSO ₄)
Texas	1	1	6.2	380	-.628
	2	2	5.42	4500	-.581
	3	3	8.60	500	-.635
	4	4	7.60	195	-.625
New Jersey	1	5	6.40	3100	-.610
New York	1	6	8.20	1680	-.635
	2	7	8.85		-.625
	3	8	8.31	9000	-.625
	4	9	6.67	8000	-.612
	5	10	6.00	13750	-.580
	6	11	4.90	15750	-.602
	7	12	7.05	5400	-.618
	8	13	7.50	2400	-.595
	9	14	4.7	13300	-.560
	10	15	5.5	18500	-.566
	11	16	6.0	8000	-.605
	12	17	6.9	3800	-.623
	13	18	4.6	22000	-.572
Maryland	1	19	7.30	2800	-.601
	2	20	7.25	1000	-.595
New Hampshire	1	21	6.25	8800	-.581
Massachusetts	1	22	7.25	3600	-.628
Wisconsin	1	23	8.4	1180	-.563
	2	24	7.4	1920	-.640
Ohio	1	25	6.9	1420	-.576
	2	26	8.2	2200	-.605
Minnesota	1	27	7.7	8000	-.612
	2	28	8.1	9100	-.630
	3	29	8.2	5000	-.600
	4	30	7.62	2800	-.588
Georgia	1	31	7.8	3800	-.666
	2	32	7.5	1400	-.645
	3	33	7.3	6000	-.605
	4	34	5.4	2400	-.595
Illinois	1	35	8.00	2500	-.663
	2	36	7.95	1940	-.640
	3	37	7.75	1320	-.610
	4	38	7.42	1130	-.624
	5	39	8.1	1700	-.655
W. Virginia	1	40	8.97	1700	-.630
	2	41	6.3	1850	-.619
Nebraska	1	42	9.0	1560	-.657
	2	43	8.95	1850	-.660
	3	44	8.20	1900	-.644
	4	45	9.3	850	-.660
	5	46	10.1	480	-.670
	6	47	10.35	420	-.700
Kentucky	1	48	6.05	1600	-.567
			Average.....		-.617

50 meter-ohms). A plot of potential as a function of pH is shown in Figure 3 which indicates that while there is a tendency for soils of high pH to produce more negative potentials, the scatter at any given pH effectively obscures any definite relationship between pH and potential.

Of interest is the difference in the change of potential with time. In Figures 4, 5, and 6 are shown the changes of voltage of each of ten lead electrodes with time for three typical classes of time-potential behavior. In the soil in Figure 4 which is neutral, and of medium resistivity, the potential of lead cable

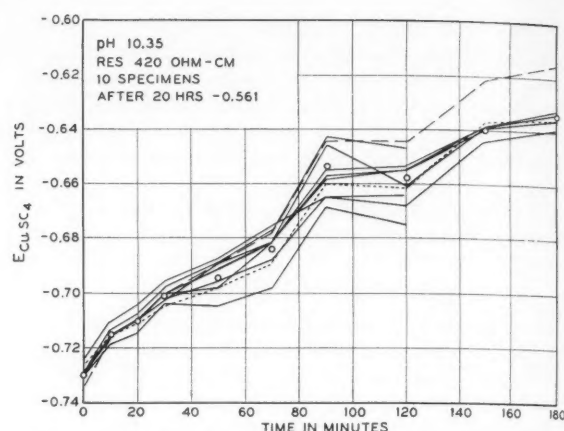


Figure 5—Time-potential curve of "bright" cable sheath in soil No. 47.

sheath is quite stable and does not show much spread in values. In highly alkaline soil of low resistivity, as shown in Figure 5, the potential upon first contact with the soil is quite negative but gradually shifts in the positive direction by about 200 millivolts over a 20 hour period. The acid and high resistivity soil in Figure 6 produces an entirely different effect upon the potential, starting somewhat less negative than the average, shifting in the positive direction by about 100 millivolts, then immediately swinging back to a value 50 millivolts more negative than the starting potential. The majority of the soils produce curves similar to Figure 4 with perhaps more scatter and more drift to less negative value with time. In some instances a reversal of the behavior in Figure 6 is encountered. In this study the author has been interested primarily in determining the potential of "bright" or anodic lead in soils. It is this potential that must be reached or exceeded by cathodic polarization to assure prevention of corrosion, according to Mears and Brown.⁵

The dynamic potential measurements have been quite enlightening. Examples are given in Figures 7 to 10 inclusive which cover a range of acidities from pH 4.6 to pH 10. The current densities given are averaged over the area of the specimen used. They are far from the actual values since variations in the character of the electrode surface and the soil in contact with it tend to concentrate the current at small areas which are favorable from both the potential and resistance standpoint.

It should be emphasized that the small change in the anode potential for fairly high current densities was completely unexpected and is not generally recognized. This is an important observation and reveals that lead dissolves in soil with very little polarization. These data indicate that under certain conditions the corrosion of lead by current discharging from it, cannot be detected with certainty by potential measurements. Unless a potential gradient in the earth is observed, indicating current leaving the structure, the potential of the anode has little significance. In these curves it is to be observed that an apparent

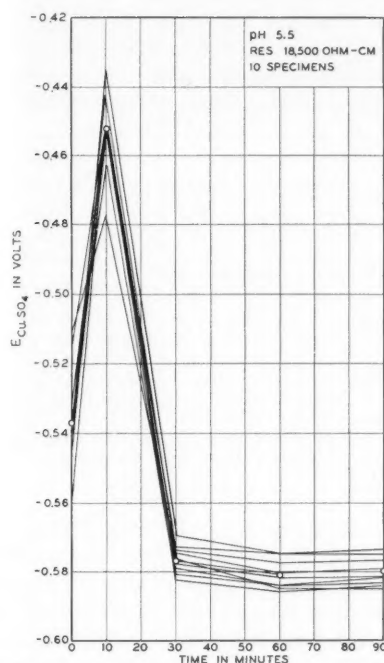


Figure 6—Time-potential curve of "bright" cable sheath in soil No. 15.

current density of 0.25 to 1.0 milliamperes per square inch is required to produce a 50 millivolt change in the anode potential. Differences of as much as 230 millivolts between "bright" lead and filmed lead have been observed in the laboratory. A shift in potential of even less magnitude from "bright" to filmed lead could be misinterpreted as indicating corrosion whereas it actually might indicate passivity with little or no corrosion.

The spread between the potentials of the anode and cathode at the start of the run as in Figure 10 may be caused by: (1) the natural scatter in values of potential between similar electrodes in the same medium, (2) the polarization produced by the very small current required to balance the bridges, or (3) both (1) and (2). In each curve the initial static potential is given. Trial runs with different electrodes, and successive runs with the same electrodes gave displacements approximately equal to the differences in static potential but produced relatively little difference in the shape of the curve. In Figure 9 is shown the effect of reversing the direction of current immediately after the initial polarization measurements have been completed. Both electrodes show the effect of changes in the composition of the soil resulting from the passage of current.

The field measurements on buried lead plates at Chester, N. J. which have been held at nominal polarization potentials of -0.75 , -0.85 , -1.00 , -1.20 and -1.50 v, are shown in Figure 11. They provide confirmation of the shape of the curves produced in the laboratory with respect to potential but indicate that equivalent polarization is produced with much less current. The ratio of laboratory current on bright lead to the field current on old or filmed lead is about

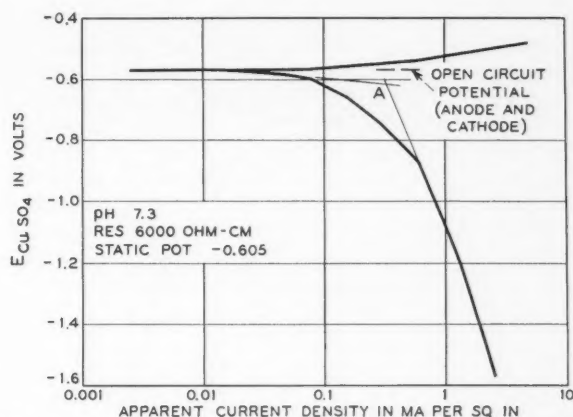


Figure 7—Anodic and cathodic polarization curves of "bright" cable sheath in soil No. 33.

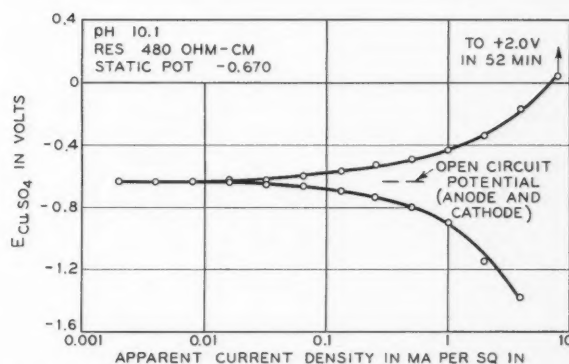


Figure 8—Anodic and cathodic polarization curves of "bright" cable sheath in soil No. 46.

200 to 1. It was noted that there was a rapid decrease in the current required to maintain the potentials during the first few days of the test. As shown in Figure 11 there was little difference between 42 days and 272 days indicating that a steady state had been reached. A buried, unpolarized lead plate assumed a steady potential of about -0.560 volt whereas the freshly cleaned or "bright" lead exhibited a potential of -0.610 volt at this site.

Discussion

In most papers on corrosion, idealized polarization curves are shown with the potential of the anode and the cathode separated by some significant value of potential at zero current. Polarization moves the potentials together as current density is increased when the source of the current is internal. In the work described in this paper the polarization is produced by current supplied from an external source; the anodes and cathodes polarize away from each other. While it is recognized that small polarized cells exist over the surface of the "bright" lead electrode their influence on the polarization curves is insignificant in view of the very large externally supplied current as compared to the small local cell currents.

The difference in the polarity of the corroding elec-

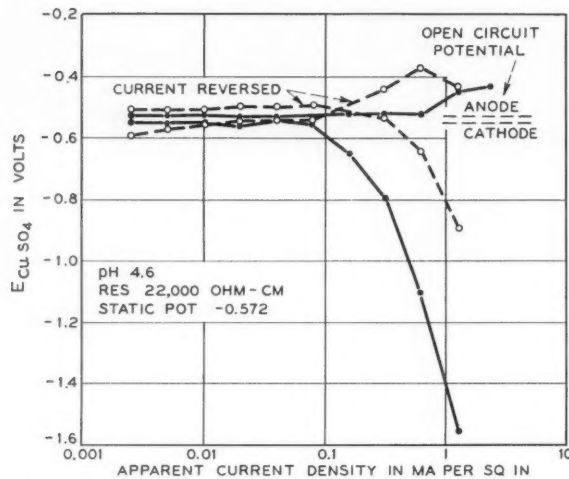


Figure 9—Anodic and cathodic polarization curves of "bright" cable sheath in soil No. 18.

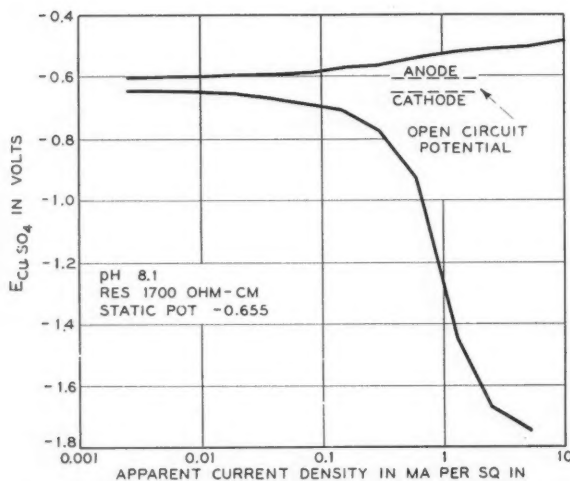


Figure 10—Anodic and cathodic polarization curves of "bright" cable sheath in soil No. 39.

trode, depending upon whether the energy comes from outside as a stray current or internally from dissimilarities in potential on the surface of the sheath, must be recognized. With current from external sources the positive electrode corrodes; with an internal current source, the negative electrode corrodes, as is exemplified in the dry cell. It is the purpose of the cathodic protection to apply a counter current to this corroding electrode until all current in the corroding direction is stopped. Usually a small excess in the opposite direction is required as a safety factor. When the source of the energy causing the corrosion is internal, cathodic protection is not "forced drainage," a term that should be restricted to the control of stray current.

As another example of this difference in polarity, consider two specimens of cable sheath immersed in soil water. One is coated with a film and measures $-0.52v$ to the copper sulfate electrode whereas the other is freshly cut bright lead and measures $-0.66v$.

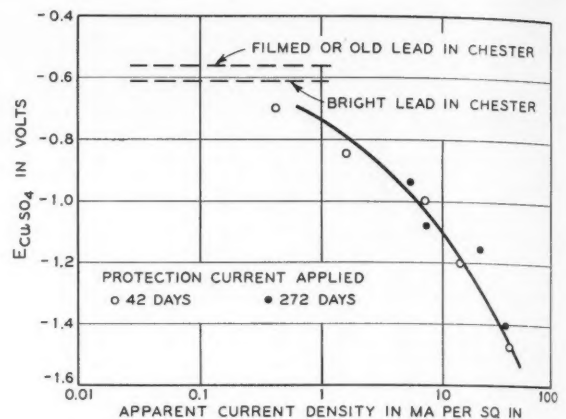


Figure 11—Cathodic polarization curve of lead-antimony cable sheath after prolonged burial in a swamp.

When coupled together the negative element will corrode just as the sheath of new cables tends to corrode when bonded to older and heavily filmed sheath.

The cathodic areas in the galvanic or non-stray current corrosion under consideration above will be positive to the corroding or anodic areas when measured to an external reference electrode in the soil. When the cathodic protection current is applied, they are polarized in the negative direction to the potential that is required to suppress the corrosion on the anodes or slightly more. At this new potential, current tends to flow toward all parts of the metal surface from an external anode and tends either to reduce oxygen or to evolve molecular hydrogen.

Without going into the subject of hydrogen overvoltage in great detail, reference can be made to the work of Tafel⁶ who stated that when the current strength is proportional to the rate at which atomic hydrogen is removed in the form of molecules, the cathodic overvoltage is given by the expression:

$$E = a + b \ln I$$

where a and b are constants. Thus, if potential is plotted on a linear scale and current density on a logarithmic scale as in Figures 4 to 11, the current density range in which the above relationship is operating can be determined.

In Figure 7, for instance, a counter current is required to suppress local cell corrosion at a potential of about $-0.57v$ until the current density reaches $.02$ ma per sq in. A gradual shift in potential occurs as the current density continues to increase until it reaches about $.08$ ma per sq in. At this point most of the current from the corroding areas has been blocked and a rapid change in potential appears which indicates the influence of hydrogen overvoltage.

At slightly higher current densities the log of the current density tends to become a linear function of the potential as indicated above. If RI drop could be completely eliminated from the measurements, the break in the curve would be a sharp knee, and the

point at which protection was complete would be the knee.

Ewing,⁷ Logan and others⁸ assume that protection is achieved at the point where the straight line of the Tafel equation curve intercepts the extension of the straight line through values of potential at low current densities as at point A in Figure 7. Mears, Brown⁵ and others have referred to the open circuit potential of the anode as the point at which cathodic protection is achieved which is equivalent to the Ewing-Logan concept. The author has found these "criteria" difficult to apply in the case of underground cable sheath, and prefers to make the cable sheath slightly more negative than the potential of freshly scraped or bright lead in the particular soil or soil water. If this margin is set at 100 millivolts, an adequate factor of safety is provided.

Conclusions

The potential of "bright" lead bears some relation to the pH of soils, but other factors that have not been isolated obscure this relation by giving a spread of about 60 millivolts at any given pH. From the data plotted in Figure 3 the most probable value for the potential to the saturated copper sulfate electrode at a pH of 5 is $-0.56 \pm .03$ volt and at a pH of 9 is $-0.64 \pm .03$ volt.

An examination of the curves in Figures 7 to 11 reveals that polarizing lead cable sheath to a potential about 100 millivolts more negative than the static potential of "bright" lead will assure cathodic protection with some margin of safety. In all cases observed, this margin assures that the current density and potential are beginning to follow a Tafel equation for the overvoltage of hydrogen on the cable sheath. In some cases where the break is sharper a lesser margin might be used.

At potentials close to the static potential of "bright" lead, corrosion may be taking place by the anodic solution of lead as shown in the anodic polarization curves in Figures 7 to 10 and be undeterminable by potential measurements. This situation results from the fact that a "passivity" may exist with little or no corrosion, but with a potential of "passive" lead somewhat less negative than that of "bright" lead. If this difference is as much as 200 millivolts it is quite likely that it is not caused by "passivity" but that it is due to anodic polarization of the lead.

Once it has been decided that cathodic protection is required, the potential of the entire cable section must be carried more negative than the static potential of "bright" sheath in the particular soil by a margin which these data indicate to be about 100 millivolts. For most soils this is achieved at a potential of -0.70 volt to the copper sulfate electrode.

As the potential is increased beyond this point and an excessive polarization is produced, a concentration of OH^- ions will develop at the sheath surface raising the pH to values above 10. Under these conditions the lead will be attacked by the caustic produced and what has been termed "cathodic corrosion" will occur. The exact danger point is hard to define as the composition of the soil, the rate of

diffusion of the caustic away from the surface of the cable sheath, the flushing of the surface with soil water, etc., will all have an effect. Under most soil conditions the protection current should be adjusted to give a potential within the range from -0.70v minimum to -0.85v maximum. In some soils this maximum can be raised to -1.0v without too much danger. If these values are real, without errors of measurement, satisfactory cathodic protection can be expected. Outside of this bracket, corrosion may be encountered which will lead to sheath failure.

Acknowledgment

The assistance and inspiration of Vernon B. Pike in much of the laboratory work and in the preparation of the manuscript is gratefully acknowledged. The author is further indebted to his many friends in the field who gathered samples of soil and contributed field measurements to supplement those made in the laboratory.

References

1. H. H. Uhlig. Corrosion Handbook. John Wiley and Sons, p. 923.
2. Gatty and Spooner. Electrode Potential Behavior of Corroding Metals in Aqueous Solutions. Oxford Press, 1938.
3. U. R. Evans. Metallic Corrosion, Passivity and Protection. E. Arnold & Co., London, 1937.
4. K. H. Logan. Underground Corrosion, U. S. Bureau of Standards Circular C450. US Gov't Printing Office, 1945.
5. R. B. Mears and R. H. Brown. *Trans. Electrochem. Soc.*, **74**, 519 (1938).
6. Tafel. *Z. Physik. Chem.*, **50**, 641 (1905)
7. S. P. Ewing. Determination of the Current Required for Cathodic Protection. *Proc. Am. Gas. Assn.* 1940, 613.
8. Logan, Pearson, Denison, Hadley and Smith. *Petroleum Engineer, Reference Annual*, 168, 1943.

DISCUSSION

Questions by Francis W. Ringer, Narberth, Pa.:

1. How do you recommend that field personnel take potential readings on a cable run where it is impractical to set up a bridge circuit to null out the IR drop in the environment?
2. Where a cable is under cathodic protection from a rectifier, can valid potential readings be taken by turning off the rectifier and then immediately taking the potential reading before polarization decays?

Replies by K. G. Compton:

1. If a bridge circuit cannot be used, and if the reference electrode cannot be placed near the structure the only thing left to do is to place it as near as possible and estimate the IR drop error as nearly as possible.
2. Valid potential readings cannot be made by interrupting the cathodic protection current and quickly reading the potential. Interrupters and oscillographic equipment have been tried over many years in studying hydrogen overvoltage. The overvoltage and part of the polarization due to concentration change more rapidly than it is possible to catch in a measurement of the kind suggested and hence leads to a considerable error.

Question by Sidney E. Trouard, New Orleans Public Service Inc., New Orleans, Louisiana:

In this paper, the average open circuit potential of lead in soils from 48 states is mentioned as being approximately -0.6 volt to a CuSO_4 electrode. Full cathodic protection is said to be achieved at -0.70 v, or Δv of 0.1 v. Mention also is made that if potentials of lead sheaths are more negative than -1.00 volt to a CuSO_4 electrode, cathodic corrosion of the lead is likely to occur. Since the spread between open circuit potential and full protection is only 0.1 volt, does it not follow that in order to avoid cathodic corrosion in the vicinity of the drain point, it would be advisable to use many small rather than one large or heavy drain point? Use of a single drain point may produce

potentials more negative than -1.0 v at the drain point in order to secure at least -0.7 v at the far end of a system.

Reply by K. G. Compton:

The paper states that in some soils the open circuit potential of bright lead may be of the order of -0.56 v and in others as negative as -0.64 v and that cathodic protection appears assured at a potential about 100 millivolts more negative than these values. Ideally a series of point anodes or a continuous anode would aid in avoiding over-protection, but this may not be practicable. Hence a calculated risk must be taken in overprotecting in one point to achieve adequate protection at another.

Any discussions of this article not published above will appear in the December, 1956 issue.

Structure of Oxide Scales on Nickel-Chromium Steels*

By H. J. YEARIAN,⁽¹⁾ H. E. BOREN, JR.,⁽²⁾ and R. E. WARR⁽³⁾

Introduction and Methods

IN A RECENT publication the results of an X-ray diffraction investigation of the scales formed on the simple chromium steels under various conditions were given and correlations made between oxide type and protectiveness of the scale.¹ Certain interpretations in terms of oxidation mechanisms also were possible. The object of the present research was to obtain similar correlations in the case of the Ni-Cr steels.

A detailed survey of the oxides formed on Ni-Cr steels which covered the whole field of possible alloy compositions would be a very lengthy task, and in some respects an unrewarding one. The investigations have been restricted, therefore, to the selected group of alloys shown in Table 1. These alloys were chosen to cover the maximum range of protectiveness using the minimum number of samples which would be representative of the alloys of this type which are in common use. Two pairs, AC-4 and 5 and AC-6 and 7 were included to test the effect of Si. The samples W were wrought materials while samples AC were cast materials⁽⁴⁾ from the same ingots as used by Brasunas, Gow, and Harder² in their very extensive rate of attack measurements. In order that direct comparisons could be made, the exposure conditions were identical with those used by these investigators; namely, 100 hours at temperatures of 1600, 1800, 2000 and 2200 F in air which had been saturated with water at 90 F, flowing at a rate of 200 cm³/min. Samples approximately 1-inch x 3/4-inch x 1/8-inch were polished through 3/0 emery papers, vapor degreased and oxidized in a platinum wound resistance furnace.

Specimens for Debye-Scherrer X-ray diffraction analysis were made by grinding samples of scale or scale layers obtained by flaking, scraping or controlled abrasion. The data were corrected for film shrinkage and the effects of specimen eccentricity and absorption. Diffraction patterns of the external and internal surfaces of scales and scale layers also were obtained by back reflection and Philips geiger counter spectrometer methods. The oxide phases present were determined from the interplanar spacing and lattice parameter values in the usual way and the relative amounts of the phases were found by comparison of the intensities of the diffraction lines with those observed with known mixtures.

Identification of the rhombohedral phases α Fe₂O₃,

Abstract

The structure of the scales formed on a series of typical Ni-Cr steels when oxidized for 100 hours in air at temperatures from 1600 F to 2200 F were investigated by X-ray diffraction methods. The scales are of two distinct types. The principal and definitive constituent of the more protective type is Cr₂O₃. A solid solution of Fe₂O₃—Cr₂O₃ also may be present; in such cases its Fe₂O₃ content tends to increase with attack rate at any given temperature. For very low attack rates considerable amounts of MnCr₂O₄ occur when the alloy contains a few tenths percent of Mn. As the attack rate increases this Mn-chromite spinel is replaced by a Ni-Cr-Fe spinel, the amount and the alloying element content of which increase with temperature and with the Ni level of the alloy. For an 80 Ni—20 Cr alloy, NiO is also present.

When the attack rate becomes excessive the scale changes to a type containing no Cr₂O₃ phase but consisting of one or more Fe₂O₃—Cr₂O₃ solutions and Ni-Cr-Fe spinels. The ferric-chromic oxide solution tends to concentrate in the outer layer and it then contains less than 10 mole percent Cr₂O₃; the proportion may increase when it occurs in an inner layer. Spinels are present in all layers but their content of the alloying elements increases in the inward direction.

These results are compared with existing data and interpreted using a theory of selective oxidation and depletion.

3.2.3

Cr₂O₃ and their solid solutions and of the cubic phases NiO, FeO and their solutions, was straightforward from existing structural data. One can expect any solid solution of the spinel type components FeFe₂O₄, NiFe₂O₄, FeCr₂O₄, NiCr₂O₄ to occur inasmuch as these oxides are miscible in all proportions. A detailed investigation of the spinel phases in these more complex circumstances would be even more difficult than in the case of the chromium steels for which a spinel lattice parameter measurement does not give a unique determination of spinel composition.^{1,3} However in the present instance the total range of lattice parameter involved is larger and certain general classifications and deductions regard-

TABLE 1—Composition of Alloys¹ (Weight Percent)

Sample	Cr	Ni	C	Mn	Si	P	S	N
AC-1.....	11.0	8.3	0.45	0.75	1.28	....	....	0.06
AC-2.....	15.7	8.2	0.45	0.75	1.20	....	....	0.06
W-1.....	18.37	9.16	0.12	0.63	0.37	0.021	0.012	....
AC-3.....	21.1	8.2	0.45	0.75	1.25	....	....	0.07
AC-4.....	25.6	12.1	0.47	0.77	1.23	....	....	0.05
AC-5.....	26.01	11.45	0.33	0.49	0.56	....	....	0.122
AC-6.....	26.5	19.9	0.30	0.59	2.51	....	....	....
AC-7.....	25.47	20.12	0.46	0.68	1.12	....	....	0.046
W-2.....	25.	20.	0.25	2.0	1.5	....	....	....
W-3.....	0.001	25.0	....	0.01	0.05	....	....	....
AC-8.....	15.98	36.43	0.45	0.80	1.24	....	....	0.075
AC-9.....	16.15	35.50	0.48	0.80	1.33	....	....	0.069
AC-10.....	25.92	35.94	0.49	0.74	1.22	....	....	0.093
AC-11.....	10.98	63.03	0.32	0.90	1.36	....	....	0.008
W-4.....	18.96	80.80	0.03	0.0	0.01	....	....	....

¹ Balance Fe.

Note: AC samples are cast ingots, W samples are wrought.

*Submitted for publication July 18, 1955. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.

⁽¹⁾ Professor of Physics, Purdue University, Lafayette, Indiana.

⁽²⁾ Applied Physics Laboratory, Johns Hopkins University, Baltimore, Md.

⁽³⁾ Diamond Ordnance Fuze Laboratories, Mine Fuze Branch, Washington, D. C.

⁽⁴⁾ Samples furnished by H. S. Avery and the American Brake Shoe Company.

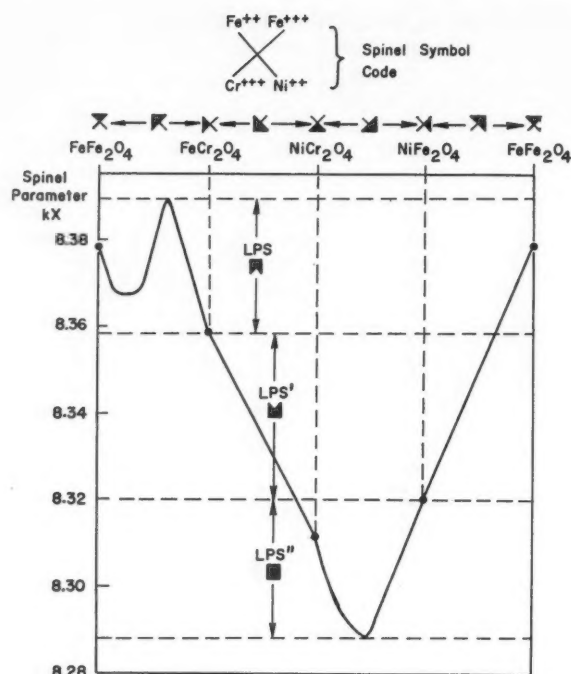


Figure 1—Lattice parameter variation^{3, 12} and symbols for the spinels which may occur in the oxides on Ni-Cr steels. LPS contains Cr, Ni or both; Ni not to exceed 0.45 mole fraction of NiFe_2O_4 . LPS' contains Ni and may contain Cr. LPS'' contains both Ni and Cr. In general, the amount of the alloying element or elements increases as the parameter decreases in each range.

ing the spinel composition can be made as shown in Figure 1. Thus the spinels can be divided into three groups (i.e., LPS, LPS' and LPS''), according to lattice parameter. Except for short ranges in the first and last groups a decrease in parameter denotes an increase in the amount of the corresponding alloying element, or elements, present in the spinel. In the case of the two binary alloys W-3 and W-4 the spinel formulae can be written explicitly.

Results

The results of the analysis are shown in Tables 2-5. The numbers in the first row of each block are the mole fractions of the phases indicated by letter symbol or formula in the second row. The rhombohedral phases are shown by the symbol R followed by a number giving the mole fraction of Cr_2O_3 dissolved in $\alpha\text{-Fe}_2\text{O}_3$; RO is $\alpha\text{-Fe}_2\text{O}_3$ and R100 is Cr_2O_3 . Spinel phases having lattice parameters lower than 8.387 kX are indicated by LPS, LPS' and LPS'' as defined in Figure 1 and discussed above, with the parameter value given below the symbol. The symbol HPS is used to represent MnCr_2O_4 or this compound with small substitution of Fe and/or Ni. All parameters are given in kX units (1 kX unit = 1.00202 Å unit) for the reason that nearly all corresponding data in the literature are in these units even when indicated as Angstrom units.

The data for different layers of the scale are separated by dashed lines; they are listed in order with

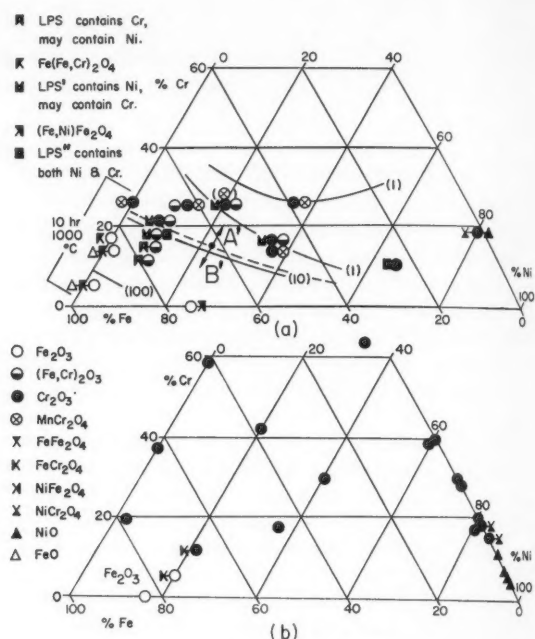


Figure 2—Oxides in the scale of Ni-Cr-Fe alloys oxidized 100 hours in air at 1800 F. Top figure is for present research; (1) and (10) 1 and 10 mg/cm²/day metal loss, respectively.² Bottom figure shows principal constituents at 1830 F according to Lustman.⁵

the outermost layer at the top. The number in parenthesis at the lower right of each box is the rate of attack in mg/cm²/day metal loss as taken or estimated from the data of Brasunas, Gow and Harder.² The oxide phases observed at 1800 F also are displayed graphically in Figure 2 (Diagram a).

A' and B' Scales

Examination of these results shows that the scales can be divided into two types, A' and B'. They are characterized by the presence or absence, respectively, of Cr_2O_3 and have the same general properties as the A and B scales on chromium steels.¹ The A' type occurs under low and the B' type under high rate of attack conditions. A transition from A' to B' scale takes place as the temperature is increased or as either the chromium or the nickel content of the alloy is decreased. By inspection of Tables 2-5 or Figure 2 it is evident that the transition occurs at an attack rate between 5 and 10 mg/cm²/day at all four temperatures. The change occurs at the same critical rate as was observed for a similar transition from a more protective A to a less protective B type scale in the case of the chromium steels¹ but the transition is repressed to alloys of lower chromium content. Thus nickel has a specific effect in inhibiting formation of the less protective scale.

The characteristic constituent of A' scale is Cr_2O_3 and it is no doubt the most important phase in determining the protective properties of this type of scale. The Cr_2O_3 often is accompanied by a solid solution of 5 to 60 mole percent of Cr_2O_3 in Fe_2O_3 . Although the occurrence of this constituent is rather

erratic, the amount of this phase and its Fe_2O_3 content tend to increase with the attack rate at any given temperature. The increase in the amount of the phase with attack rate is similar to the behavior of an Fe_2O_3 phase in the protective A type scale on the simple chromium steels. In that case, however, no Cr_2O_3 was found in solution¹; all Cr_2O_3 occurred as the separate principal phase. Thus the presence of Ni in the alloy promotes the formation of the solutions in preference to Fe_2O_3 and this may be one of the important functions of the Ni in improving the protectiveness of the scale.

On the alloys containing a few tenths percent of Mn the A' scale may contain MnCr_2O_4 , especially at the lower attack rates. The relative amount of this phase is surprising; ten to fifteen percent of the metal in the scale may be Mn. As the Ni level of the alloy, or the temperature of oxidation, is increased the MnCr_2O_4 spinel is replaced by an Fe-Cr-Ni spinel (by NiCr_2O_4 on the alloy which contains no iron). As these variables are increased further the amount of the new phase, and also its content of the alloying elements, tends to increase. The transition to the new spinel seems to occur at an attack rate of approximately 1 mg/cm²/day metal loss. An MnCr_2O_4 phase also was observed in the protective A scale on simple chromium steels, but in that case it was not replaced by an Fe-Cr spinel.¹ No other spinel occurred in A type scale.

Sample W-4 is a special case since it is a binary alloy containing no iron. Because of the large amount of Ni in the alloy the copious amounts of NiO observed in the scale may not be unexpected, but it is perhaps surprising that this scale is so protective in view of the fact that the structure of NiO is analogous to that of wüstite. Transport by diffusion in NiO is much less than in FeO. It is larger than in Cr_2O_3 , however, and it is increased by solution of Cr_2O_3 .⁴ The difficulty would be obviated if the NiO segregated into a separate layer, but there is no evidence that this occurs.

TABLE 2—Structure of Oxide Scales on Nickel-Chromium Steels¹ (8-12 Percent Ni)

Temp. (Degs. F)	AC-1			AC-2			W-1			AC-3			AC-4		
	11.0 Cr-8.3 Ni			15.7 Cr-8.2 Ni			18.37 Cr-9.16 Ni			21.1 Cr-8.2 Ni			25.6 Cr-12.1 Ni		
1600	.40 LPS 8.376	.60 R5...		.20 LPS 8.370	.75 R4...	.05 R100	.40 LPS 8.372	.55 R4...	.05 R100	.20 HPS 8.435	.10 R10...	.70 R90	.20 LPS 8.322	.50 R12...	.30 R100
	.30 LPS 8.374	.70 R4 (23)				(27)			(1.1)			(0.3)			(0.2)
1800	1.0 R5			.20 LPS 8.365	.80 R6...		.50 LPS 8.348	.50 R9...		.25 LPS 8.322	.70 R10...	.05 R100	.10 HPS 8.418	.40 R15...	.40 R100
	.60 LPS 8.375	.40 R8 (52)		1.0 LPS 8.383		(27)	1.0 LPS 8.317		(11)			(4.0)			(1.0)
2000	.40 LPS 8.375	.60 R5...		.10 LPS 8.362	.90 R5...		.50 LPS 8.355	.50 R9...		.20 LPS 8.348	.50 R27...	.30 R93	.20 LPS 8.340	.40 R40...	.40 R100
	1.0 LPS 8.380		(115)	.40 LPS 8.377	.30 R8...	.30 R78 (115)	1.0 LPS 8.386		(37)			(5.1)			(2.8)
2200	.10 LPS 8.37	.90 R10...		.40 LPS 8.334	.60 R4...		.20 LPS 8.347	.80 R4...			.30 R45...	.70 R100		.20 R45...	.80 R100
	1.0 LPS 8.325		(270)	.70 LPS 8.309	.30 R56...		.40 LPS 8.322	.60 R23 ...				(5.5)			(3.0)

¹ Steels were oxidized for 100 hours at temperatures indicated in air saturated with water at 90 F.

Note: Numbers in the first row are the mole fractions of the phases indicated in the second row, as follows:

1. Rn—Rhomboidal phase, n mole percent of Cr_2O_3 in α Fe_2O_3 solid solution; R100 is Cr_2O_3 .

2. HPS—Spinel phase, MnCr_2O_4 ; lattice parameter between 8.412 and 8.435 kX (range due to partial substitution of Fe and/or Ni). LPS—Spinel phase, lattice parameter between 8.387 and 8.359 kX; contains Cr, or Ni not to exceed 0.45 mole fraction of NiFe_2O_4 . LPS'—Spinel phase, lattice parameter between 8.358 and 8.321 kX; contains Ni, may contain Cr. LPS''—Spinel phase, lattice parameter between 8.320 and 8.290 kX; contains both Ni and Cr.

A decrease in lattice parameter within each range corresponds to an increase in the content of alloying elements. (Parameter is given in kX below spinel symbol, 1 kX = 1.00202A.)

Data for different layers are listed in order with the outermost layer at the top. Number in parenthesis at the lower right is the metal loss² in mg/cm²/day.

TABLE 3—Structure of Oxide Scales on Nickel-Chromium Steels¹ (20-25 Percent Ni)

Temp. (Degrees F)	W-3			AC-6			AC-7			W-2		
	0.00 Cr-25.0 Ni			26.5 Cr-19.9 Ni			25.47 Cr-20.12 Ni			25 Cr-20 Ni		
1600	.40 LPS 8.376	.60 RO...		.20 HPS 8.428	.80 R100 (0.2)		.10 HPS 8.429	.20 R10...	.70 R100 (0.4)	.30 HPS 8.423	.70 R100 (0.4)	
	$\text{Ni}_{.05}\text{Fe}_{.95}\text{Fe}_2\text{O}_4$					(38)						
1800	.50 LPS 8.348	.50 RO...		.20 HPS 8.414	.80 R100 (0.3)		.20 LPS 8.368	.40 R23...	.40 R75 (0.9)	.40 LPS 8.325	.30 R12...	.30 R93 (0.9)
	$\text{Ni}_{.53}\text{Fe}_{.47}\text{Fe}_2\text{O}_4$					(110)						
2000	.40 LPS 8.340	.60 RO...		.40 LPS 8.332	.20 R15...	.40 R100	.20 LPS 8.314		.80 R100	.60 LPS 8.34	.30 R50...	.10 R10
	$\text{Ni}_{.67}\text{Fe}_{.33}\text{Fe}_2\text{O}_4$											
2200	.60 LPS 8.339	.40 RO ...										
	$\text{Ni}_{.69}\text{Fe}_{.31}\text{Fe}_2\text{O}_4$											
2200	.30 LPS 8.356	.70 Fe ₇ Ni ₃ O (270)				(0.8)			(1.8)			(1.8)
	$\text{Ni}_{.4}\text{Fe}_{.6}\text{Fe}_2\text{O}_4$											
2200	.50 LPS 8.336			.50 R100 (2.3)			.20 LPS 8.329		.80 R100 (2.8)	.30 LPS 8.350	.30 R61...	.40 R100 (2.8)

¹ Steels were oxidized for 100 hours at temperatures indicated in air saturated with water at 90 F.

Note: Numbers in the first row are the mole fractions of the phases indicated in the second row, as follows:

1. Rn—Rhomboidal phase, n mole percent of Cr_2O_3 in α Fe_2O_3 solid solution; RO is α Fe_2O_3 , R100 is Cr_2O_3 .

2. HPS—Spinel phase, MnCr_2O_4 ; lattice parameter between 8.412 and 8.435 kX (range due to partial substitution of Fe and/or Ni). LPS—Spinel phase, lattice parameter between 8.387 and 8.359 kX; contains Cr, or Ni not to exceed 0.45 mole fraction of NiFe_2O_4 . LPS'—Spinel phase, lattice parameter between 8.358 and 8.321 kX; contains Ni, may contain Cr. LPS''—Spinel phase, lattice parameter between 8.320 and 8.290 kX; contains both Ni and Cr.

A decrease in lattice parameter within each range corresponds to an increase in the content of alloying elements. (Parameter is given in kX below spinel symbol, 1 kX = 1.00202A.)

Data for different layers are listed in order with the outermost layer at the top. Number in parenthesis at the lower right is the metal loss² in mg/cm²/day.

The less protective B' type scale is characterized by the absence of Cr_2O_3 and the presence of an LPS type phase. The latter is, of course, not unique to the B' scale because it also occurs in the A' scale. As in the A' scale, no Fe_2O_3 phase is observed (except on sample W-3 which contains no Cr) but a solid solution of Cr_2O_3 in Fe_2O_3 occurs instead. The Cr_2O_3 content of the solution is rarely larger than 10 mole percent and then only when the solution is present in inner layers. Thus there is a tendency for segregation of these solutions so that the one which is lowest in Cr_2O_3 is on the outside of the scale.

The spinels show a similar tendency. With a few exceptions, which may be within the uncertainty evident in Figure 1, the amount of the alloying elements present in the spinel is largest in the inner layer and smallest in the outer layer.

The opposite trend is noted for sample W-3 containing no chromium (i.e., in the absence of chromium the nickel-rich spinels tend to segregate at the outside of the scale.) It will be noted that the spinels are not confined to the inner layers but usually occur, in reduced amount, in the outer layer as well. In the B type scales on chromium steels a series of Fe—Cr spinels, running from FeCr_2O_4 at the oxide-metal interface to Fe_3O_4 in intermediate layers was observed, but in that case the outermost layer was pure Fe_2O_3 .¹ The series of spinels often was accompanied by FeO, so perhaps the most striking difference between B' and B type scales is the total absence of FeO from the former even under conditions of very high attack. The suppression of FeO may be one of the important ways in which nickel affects the attack rate.

Discussion

The oxidation data obtained at 1800 F are shown in Figure 2 (Diagram a) on an alloy composition

TABLE 4—Structure of Oxide Scales on Nickel-Chromium Steels¹ (35-36 Percent Ni)

Temp. (Degrees F)	AC-8 15.96 Cr-36.43 Ni			AC-9 16.15 Cr-35.50 Ni			AC-10 25.92 Cr-35.94 Ni		
1600.....	.20 HPS 8.426	.80 R100 (0.2)		.25 HPS 8.433	.05 R7 (0.3)	.70 R100 (0.3)	.20 HPS 8.429	.80 R100 (0.6)	
1800.....	.30 HPS 8.420	.70 R100 (0.5)		.40 LPS' 8.332	.20 R20 (0.9)	.40 R100 (0.7)	.25 HPS 8.412	.75 R100 (0.7)	
2000.....	.30 LPS' 8.324	.20 R30 R100 (4.4)	.50 R100 (4.4)	.60 LPS' 8.326	.40 R100 (2.4)	.40 R100 (2.2)	.60 LPS' 8.326	.40 R100 (2.2)	
2200.....	.30 LPS' 8.319	.10 R45 R100 (9.4)	.60 R100 (9.4)	.50 LPS' 8.322	.50 R100 (7.4)	1.0 R100 (4.4)			

¹ Steels were oxidized for 100 hours at temperatures indicated in air saturated with water at 90 F.

Note: Numbers in the first row are the mole fractions of the phases indicated in the second row, as follows:

1. Rn—Rhomboidal phase, n mole percent of Cr_2O_3 in α Fe_2O_3 solid solution; R100 is Cr_2O_3 .
2. HPS—Spinel phase, MnCr_2O_4 ; lattice parameter between 8.412 and 8.435 kX (range due to partial substitution of Fe and/or Ni). LPS—Spinel phase, lattice parameter between 8.358 and 8.321 kX; contains Ni, may contain Cr. LPS'—Spinel phase, lattice parameter between 8.320 and 8.290 kX; contains both Ni and Cr.

A decrease in lattice parameter within each range corresponds to an increase in the content of alloying elements. (Parameter is given in kX below spinel symbol, 1kX = 1.00202A.)

Data for different layers are listed in order with the outermost layer at the top. Number in parenthesis at the lower right is the metal loss² in mg/cm²/day.

diagram using symbols which are related to those appearing in Tables 2-5 as shown in the key and in Figure 1. The 10 hour air oxidation data from the earlier results for the chromium steels at 1000 C (1832 F) are included for completeness. Several attack rate contours in mg/cm²/day metal loss computed from the data of Brasunas, Gow and Harder also are shown.

Lustman⁵ has summarized the principal constituents of the scale on similar alloys at 1830 F, according to existing literature. This summary is reproduced in Figure 2 (Diagram b) for comparison, using the same symbols as in the top drawing of Figure 2. It is seen that there is complete agreement with regard to Cr_2O_3 , except for the 19 Cr-3 Ni and the 11 Cr-20 Ni alloys (i.e., the A'—B' transition comes at a slightly lower Cr level, according to Lustman). The Fe_2O_3 field represented by Lustman in the iron-rich corner is interpreted by the authors as a low chrome ferric-chromic oxide solution which extends much farther into the diagram, although possibly not as a principal constituent. With respect to NiO the data agree in principle, but this oxide also is present on the 20 Cr-80 Ni alloy which is at least as resistant as that containing the maximum of 10 percent Cr for which NiO is indicated by Lustman.

Disparities In Data

The chief disparities between the data represented in Diagrams a and b of Figure 2 are (1) the absence of spinel phases from the latter, except for NiCr_2O_4 , where there is agreement, and (2) the two entries of

TABLE 5—Structure of Oxide Scales on Nickel-Chromium Steels¹ (63-81 Percent Ni)

Temp. (Degrees F)	AC-11 10.98 Cr-63.03 Ni			W-4 18.96 Cr-80.80 Ni		
1600.....	.50 LPS' 8.329	.50 R100 (0.2)				
1800.....	.50 LPS' 8.318	.50 R100 (0.4)		.05 LPS' 8.318 NiCr_2O_4	.55 NiO	.40 R100 (0.5)
2000.....	.40 LPS' 8.320	.40 NiO	.20 R100 (1.4)	.30 LPS' 8.313 NiCr_2O_4	.50 NiO	.30 R100 (1.6)
2200.....	.30 LPS' 8.318	.70 R100		.20 LPS' 8.315 NiCr_2O_4	.50 NiO	.30 R100
	.20 LPS' 8.302	.50 R100 (3.3)		.20 LPS' 8.304 NiCr_2O_4	.50 NiO	.30 R95 (2.2)

¹ Steels were oxidized for 100 hours at temperatures indicated in air saturated with water at 90 F.

Note: Numbers in the first row are the mole fractions of the phases indicated in the second row, as follows:

1. Rn—Rhomboidal phase, n mole percent of Cr_2O_3 in α Fe_2O_3 solid solution; R100 is Cr_2O_3 .
2. LPS'—Spinel phase, lattice parameter between 8.358 and 8.321 kX; contains Ni, may contain Cr. LPS—Spinel phase, lattice parameter between 8.320 and 8.290 kX; contains both Ni and Cr.

A decrease in lattice parameter within each range corresponds to an increase in the content of alloying elements. (Parameter is given in kX below spinel symbol, 1kX = 1.00202A.)

Data for different layers are listed in order with the outermost layer at the top. Number in parenthesis at the lower right is the metal loss² in mg/cm²/day.

to those key and in from the at 1000 C. Several loss com- and Harder constitu- F, accord- is repro- son, using Figure 2 t with re- and the 11 comes at a man). The iron-rich w chrome ds much y not as a o the data present on sistant as nt Cr for

FeCr_2O_4 , which one would expect to be LPS (probably containing some Ni). The spinels are considered to be principal constituents because they probably have a considerable effect on the scaling properties of the alloys, almost certainly so in the case of B' scales. For the sake of completeness, it may be remarked that the field of MnCr_2O_4 evidently extends (within the A' region) to zero iron, when the alloy contains sufficient manganese. This oxide was observed on such alloys of the 20 Cr-80 Ni type by Gulbransen;⁶ it was not found on the authors' sample W-4 because of the low manganese content.

In view of the pronounced improvement in protectiveness associated with partial substitution of nickel for iron in the alloys, one anticipates corresponding differences in the character of A' as compared with A scales and B' as compared with B scale.

Comparison of A' and A Scale

With regard to the A' scale, it is difficult to believe that the addition of a Cr-Ni-Fe spinel can be particularly beneficial. No information is available concerning the diffusion properties or the ranges of homogeneity of these spinels, but it is unlikely that diffusion through them would be slower than through Cr_2O_3 , particularly in view of the fact that very similar spinels are not ultraproductive in the B' scales. The second possibility is that the diffusion in the low chrome ferric-chromic oxide solutions in A' scales is less than in the pure α Fe_2O_3 of A scales. This seems not unlikely. As was pointed out above, presence of the solution is detrimental in that the amount of this phase correlates with attack rate, but an increase in the chromium content of the solution also correlates with a decrease in attack, suggesting that the solution is less detrimental than pure α Fe_2O_3 .

As a further indication of the undesirability of the solutions, and hence also of α Fe_2O_3 , it is to be noted that the low chrome solution correlates with the sample of least protectiveness in the case of AC-8 and AC-9 (i.e., with the latter at the two lower temperatures and with the former at the higher temperatures.) Since Fe_2O_3 diffuses oxygen^{7,8} by anion vacancies and Cr_2O_3 diffuses metal⁸ by cation vacancies, the solutions might show anomalous effects. It is to be noted that the prevalence in A' scales of these solutions rather than Fe_2O_3 implies that through some indirect process the presence of nickel causes a more dispersed formation of metastable iron oxide inclusions from which the solution can be produced more readily than is the case in A scales.¹ This greater dispersion of the more "conducting" phase may in itself account for the decrease in attack.

Neither of the above possibilities will explain why an A' scale may be superior to an A scale which apparently was an identical composition. For example, at 1800 F a Cr_2O_3 plus MnCr_2O_4 scale is observed on AC-10 (Table 4) and on a 26 percent chrome steel (Table 2, Reference 1), yet the former is more protective than the latter. Here one must invoke an explanation based either on the assumption that some undetected difference in the properties of the oxides exists, (e.g., that saturation with Ni reduces the con-

centration of vacancies in Cr_2O_3) or that the conditions at the metal-oxide interface are altered.

Effects At Interface

In the case of A scales on simple chromium steels the scales could be easily removed to reveal a very thin oxide film on the metal overlaid by an amorphous layer approximately 10^{-5} cm thick which was presumed to be amorphous silica or a silicate.¹ In the present instance, A' scales were much more tightly adherent and for that reason such thin layers beneath the scale could not be studied as thoroughly. There can be little doubt, however, that they exist and are similar to those beneath the A scales. A variation of these thin layers in the two cases could render a greater protectiveness to the Ni-Cr steels either because the layer itself causes a significantly lower transport or simply because it gives a greater adherence of the scale. A proposal of the latter type has been made by Gulbransen⁶ in a similar situation which arose during cycling tests of Nichrome Type 20 Cr-80 Ni alloys.

The difference in attack of the two pairs of samples in each of which the silicon is varied (i.e., AC-6, AC-7, and AC-4, AC-5) may be ascribed to effects taking place at the interface. There are, however, differences in the scale which may be important. Sample AC-6 has more silicon than AC-7 and at the two lower temperatures where it is two to three times as resistant, the scale contains more Cr_2O_3 and less of the low Cr_2O_3 solution. At 2000 F the opposite trend is noted but there are also changes in the spinel. AC-5 has less silicon than AC-4; the scale formed on it (not shown in Tables 2-5) is similar to that on AC-4 in all respects except that the scale contains slightly less Cr_2O_3 at the lowest temperature where it is slightly less protective than that on AC-4. Thus Si may have its chief effect on the scaling rate by influencing the formation of the sesquioxide solutions in some indirect way.

Comparison of B' and B Scales

In the case of the B' scales, again the low chrome solution may be more protective than the Fe_2O_3 which occurs in B scales. Furthermore, there is no reason not to suppose, in the absence of direct experiments, that the Fe-Cr-Ni spinels are more protective than Fe-Cr spinels inasmuch as the amount of this phase and the amount of the alloying elements contained in it correlate well with the observed degree of protectiveness. In addition, the absence of a wüstite phase would certainly be expected to improve the protectiveness of the B' scale.

Part of the general improvement in oxidation resistance conferred by the introduction of nickel is due to extension of the A' field to lower chromium alloys as compared with the A field of chromium steels. This obviously has to do with a change in the mechanism by which iron enters A type scales to initiate the formation of B scales. The absence of wüstite from the B' type of scale is another aspect of the same problem, all of which is bound up with the question of how nickel enters the scale.

The dissociation pressure of NiO is very high com-

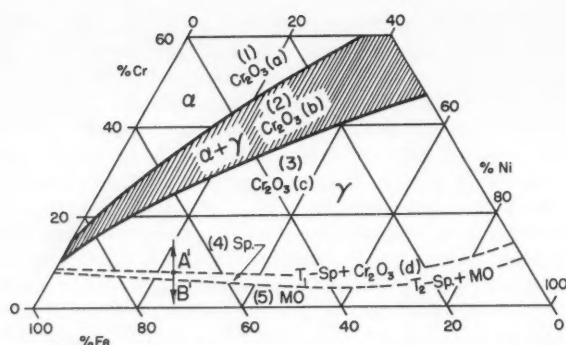


Figure 3—Constitution diagram of the Fe-Cr-Ni alloys and schematic of the oxides in equilibrium with alloys of given surface composition.

pared with that of FeO. It lies in fact⁹ in the equilibrium range of Fe_3O_4 , thus no reasonable surface depletion of iron would allow equilibrium of the alloy with NiO in preference to FeO. (Sample W-4 with no iron and possibly sample AC-11 containing only 23 percent iron are obvious special cases.) Since FeO is not observed and nickel does enter the scale in large amounts, either NiFe_2O_4 , NiCr_2O_4 , or both, must be sufficiently stable that equilibrium with the alloy can be attained at existing surface concentrations at pressures below that which is possible for FeO.

Phase Diagrams

Some insight into the problem may be obtained from considerations of possible phase diagrams. Figure 3 shows the alloy constitution diagram appropriate to temperatures in the neighborhood of 1800 F. All of the alloys presently considered lie in the γ field. The diagram has been divided into five fields corresponding to the oxides which might be expected to be in equilibrium, at suitable oxygen partial pressures, with the various alloys. Occurrence of the MnCr_2O_4 phase is a separate problem to be considered later. The arrangement shown is highly schematic and represents only one of several possibilities; it is consistent with the Case 3 considered in discussion of the Fe-Cr alloys.¹

Four types of Cr_2O_3 are required, the amount of Fe and Ni in solution increasing in the order a, b, c, d. Alloys in Field 1 can be in equilibrium with Cr_2O_3 (a). Field 2 alloys form the base of a three (solid) phase region terminating at Cr_2O_3 (b). The alloys in Fields 3, 4 and 5 form two phase regions with Cr_2O_3 (c), the spinel solutions $(\text{Fe,Ni})\text{Cr}_2\text{O}_4$ and the MO solutions, $(\text{Fe,Ni})\text{O}$, respectively. These three regions are separated by three phase regions the traces of which are marked as T_1 and T_2 and the bases of which are respectively Cr_2O_3 (d) — chromium rich $(\text{Fe,Ni})\text{Cr}_2\text{O}_4$ and chromium poor $(\text{Fe,Ni})\text{Cr}_2\text{O}_4$ — MO.

For infinitely slow oxidation, alloys above T_1 would give Cr_2O_3 and those below T_2 , MO. Since the range of solubility of Fe and Ni in Cr_2O_3 and of Cr in MO is very small, the oxides formed in each of these cases would be nearly pure. For finite oxidation rates, however, surface depletion of the oxidiz-

ing metal or metals would occur bringing the surface composition of the alloys nearer to T_1 or to T_2 . There will be a range of alloys of bulk compositions in the neighborhood of T_1 - T_2 , therefore, for which a mixture of oxides can be expected to occur in a manner analogous to that investigated quantitatively by Wagner¹⁰ in an idealized case.

This mechanism provides for the two types of scale. If the surface composition of an alloy above T_1 does not cross this contour the scale will be A', containing Cr_2O_3 or this oxide plus spinel. On an alloy of bulk composition below T_2 the oxide in equilibrium will be either MO, MO and spinel, or spinel (i.e., of the B' type.)

Whenever the spinels and/or MO are formed one can expect that the overall composition of the scale may be different from that of the oxide at the interface since the rate of diffusion through the oxide may not be the same for the different components. One also can expect a tendency for layering to occur, due to differential diffusion and the action of displacement reactions, with the oxides of higher equilibrium pressures farther from the metal-oxide interface; this should continue to an oxide form on the outside of the scale which is stable at the ambient pressure. Thus the observed data are average values for the scale or layer analyzed.

With this in mind, and within the uncertainty of composition evident in Figure 1, the results for the B' scales are consistent with a distribution of spinels of composition richer in Fe at the outside and in Ni and Cr on the inside of the scale. In the several cases for which only LPS is observed, the requirement that the spinel in contact with the metal be the appropriate $(\text{Fe,Ni})\text{Cr}_2\text{O}_4$ solution can be met only by assuming that the transition from LPS' to LPS spinels occurs in a layer too thin to be detected. The spinel in the outer portion of this scale should oxidize to either Fe_2O_3 or a low chromium $(\text{Fe,Cr})_2\text{O}_3$ solution, depending on whether the segregation of the spinels does or does not progress to essentially Fe_3O_4 before they become oxygen-rich. The former alternative was observed in B scales of the simple chromium steels¹ whereas the latter is found in the present instance.

In the case of the A' scales there is another possible way in which the pressure differential between the equilibrium value at the interface and atmospheric can be bridged. If the spinel composition remains at $(\text{Fe,Ni})\text{Cr}_2\text{O}_4$ then it may remain in equilibrium with Cr_2O_3 (d) throughout the scale. All of the spinel lattice parameters observed in A' scales are in agreement with this concept. In this interpretation any $(\text{Fe,Cr})_2\text{O}_3$ solution observed has to be ascribed to undetected variations of the B' scale type or to the consequence of non-equilibrium processes associated with the initial scaling or with rapid local attack due to cracking, blistering, etc.

Surface Composition Contours

Several further deductions can be made by comparing Figure 3 with Figure 2 (Diagram a). The A'-B' scale contour in the latter Figure represents

the bulk alloy compositions for which Cr_2O_3 becomes unstable, whereas in Figure 3 it represents the corresponding surface compositions. The contour of surface compositions has been drawn in a somewhat arbitrary way; it must, however, lie below the lowest bulk concentrations of chromium for which Cr_2O_3 is observed. In view of the depletion effect the lowest values are expected to occur in short oxidations; this was the case with the chromium steels and the observations determine the left terminus of T_1 with some degree of certainty.

When similar short period oxidations of the Ni-Cr steels are carried out it may be necessary to give T_1 a downward slope to the right but in any case such a slope will have to be small compared with that of the A'-B' boundary in Figure 2 (Diagram a). It is clear, therefore, that for a given rate of metal loss the chromium depletion in the alloy decreases as the nickel level of the alloy increases. This could occur either because the diffusion of chromium is higher in the Ni steels or because the rate of loss of chromium in Ni-Cr-Fe spinels is less than in Cr-Fe spinels. The latter must have at least some effect in order for one to understand the difference between A and A' scales which are characterized, respectively, by the absence and the presence of a spinel. This difference implies that if a simple chromium steel is depleted in chromium to the extent that the surface composition reaches T_1 and a spinel forms, depletion continues, so that the Cr_2O_3 phase disappears and B scale forms. In a Ni-Cr steel, on the other hand, formation of the spinel may stop chromium depletion and the scale may remain A' type, containing a spinel as well as Cr_2O_3 .

The downward slope of the contour of optimum bulk concentration midway between the two unit attack rate curves, and others farther up in the diagram,² would imply that selective depletion also occurs in these cases if it is assumed that the corresponding contours plotted in terms of surface composition are anything like parallel to T_1 . In these cases, barring new experiments to the contrary, it can be assumed from Figure 2 (Diagram b) and Figure 3 that the oxide is essentially pure Cr_2O_3 (except for the possibility of MnCr_2O_4). Equal rates of metal loss therefore refer to equal rates of chromium loss; selective depletion would then have to be caused by a higher diffusion coefficient of chromium in the Ni-Cr steels as compared with simple chromium steels.

From these considerations it would be assumed that the surface compositions corresponding to the optimum bulk compositions would be just above T_1 in Figure 3 (i.e., at the minimum chromium for which only Cr_2O_3 is formed.) The ten-fold increase in attack between these alloys and those at the A'-B' boundary may be ascribed to the increased transport through the spinels and $(\text{Fe,Cr})_2\text{O}_3$ solutions as already discussed.

Increased Attack Rate

Yet to be considered is the fact that the attack rate gradually rises² as the chromium concentration

of the alloys is increased above the optimum. There seem to be two possible causes for this. Such a trend might be expected by analogy with the theory of Wagner.¹⁰ This theory shows that for chromium in an ideal solid solution which oxidizes exclusively to Cr_2O_3 having a fixed composition, the equilibrium oxygen pressure at the metal-oxide interface would increase as the chromium concentration of the solution is decreased. As a consequence, the oxidation rate would become smaller because the concentration gradient of cation vacancies in the oxide would diminish. A similar decrease in gradient might occur as a result of the increase of Fe and Ni dissolved in Cr_2O_3 (a,b,c,d). Solution of divalent ions in the oxide could act to shift the equilibrium of vacancies plus hexavalent chromium ions toward fewer vacancies.⁴ If the attack rate contours on the surface composition diagram actually slope upward to the right as suggested by T_1 , Figure 3, it would be indicated that the solution of Ni is more effective than Fe in reducing the diffusion through Cr_2O_3 .

The oxidation of the 80 Cr-20 Ni alloy has not been included in the above discussion. With Figure 3 as it is drawn it would not be possible for all three phases shown in Figure 2 (Diagram a) to be in equilibrium with the metal. This would be possible, however, if T_1 and T_2 coincided, corresponding to the Case 1 of Reference 1. With the diagram as drawn, the spinel could be in contact with the metal and the outer oxygen-rich portions of it oxidized to NiO and Cr_2O_3 , or there could be local fluctuations of surface concentration which would permit all three phases.

The behavior of the MnCr_2O_4 phase may be interpreted by the Wagner concepts in the same way as was done¹ for the simple chromium steels. Although the dissociation pressure of MnO is much lower than that of Cr_2O_3 ,^{9,11} with the Mn present only to 0.5 to 1.0 percent in the alloy, the equilibrium oxygen pressure may well be higher than that existing at the interface for the high chromium alloys. If so, manganese should not appear in the scale on these alloys except to its limit of solubility in Cr_2O_3 . But as the concentration of chromium in the alloys decreases and the interfacial oxygen pressure rises, the manganese oxides evidently become stable and are formed in the scale. For still higher interfacial pressures the manganese can be expected to oxidize in a sub-scale region and not be observed in the scale.

It is evident from these discussions and speculations that much more information regarding phase diagrams, equilibrium constants and physical properties of the various oxides and their solutions will have to be obtained before anything approaching a complete description of the oxidation of these ternary alloys can be given.

Acknowledgments

The authors are greatly indebted to H. S. Avery and the American Brake Shoe Company for the samples AC taken from the ingots investigated by Brasunas, Gow and Harder. They are indebted to V. N. Krivobok of the International Nickel Company for the other samples used.

The research described in this paper was conducted under the auspices of Project Squid, jointly sponsored by the U. S. Office of Naval Research and the Office of Air Research under contract N6-ori-104, and of the U. S. Office of Naval Research under contract N7-onr-39419.

References

1. H. J. Yearian, E. C. Randell and T. A. Longo. The Structure of Oxide Scales on Chromium Steels. *Corrosion*, **12**, 514t (1956) Sept.
2. A. de S. Brasunas, J. T. Gow and O. E. Harder. *A.S.T.M.*, **46**, 129 (1946).
3. H. J. Yearian, J. M. Kortright and R. H. Langenheim. *J. Chem. Phys.*, **22**, 1196 (1954).
4. Karl Hauffe. Progress in Metal Physics. Interscience Publishers Inc., New York, 1953, Vol. 4, Chapter 2.
5. B. Lustman. Metals Handbook. Am. Soc. for Metals, Cleveland, Ohio, 1948 Edition, page 223.
6. E. A. Gulbransen and W. R. McMillan. Westinghouse Research Laboratories Technical Paper No. 1719.
7. L. Himmel, R. F. Mehl and C. E. Birchenall. *Jour. of Metals*, **5**, 827 (1953).
8. D. J. M. Bevan, J. P. Shelton and J. S. Anderson. *J. Chem. Soc.*, 1729 (1948).
9. L. S. Darken and R. W. Gurry. Physical Chemistry of Metals. McGraw-Hill, N. Y., 1953, page 349.
10. C. Wagner. *J. Electrochem. Soc.*, **99**, 369 (1952).
11. M. deKay Thompson. The Total and Free Energies of Formation of the Oxides of Thirty-two Metals. The Electrochemical Society, N. Y., 1942.
12. F. C. Romeijn. Philips Research Repts. I 8, 304 (1953); II 8, 321 (1953).

Question by Mortimer C. Bloom, Naval Research Laboratory, Washington, D. C.:

Mention is made of Fe_2O_3 — Cr_2O_3 solid solutions and separate mention is made of a Cr_2O_3 phase. Is this Cr_2O_3 phase the limit of the above solid solutions or does it have a different structure?

Reply by H. J. Yearian:

$\alpha\text{Fe}_2\text{O}_3$ and Cr_2O_3 are miscible in all proportions, forming a continuous series of solid solutions. All members of the series have the same basic rhombohedral structure with the appropriate number of iron and chromium ions distributed at random over the cation lattice sites. Since there is a unique value of cell edge and interaxial angle associated with each composition, determination of these parameters from the diffraction pattern serves to identify the composition.

Any discussions of this article not published above
will appear in the December, 1956 issue.

Corrosion of Metals by Liquid Fertilizer Solutions*

By D. C. VREELAND and S. H. KALIN

Introduction

SINCE the end of World War II the use of agricultural fertilizers in liquid form has been growing rapidly in this country. Much of the growth has taken place in the use of the so-called "nitrogen fertilizer solutions" which generally consist of aqueous solutions of ammonia, ammonium nitrate, or urea, or combinations of the three as sources of nitrogen. Recently, however, interest has been shown in "complete-mix liquid fertilizers"¹ which contain the three primary plant nutrients—nitrogen, phosphate, and potash. These solutions may contain various amounts of ammonia, phosphoric acid, potassium chloride, urea, and ammonium nitrate.

One of the main disadvantages of the liquid fertilizers is the corrosive nature of the liquids during formulation, storage, and application. In the case of the nitrogen fertilizer solutions, chromium-nickel stainless steels and aluminum alloys have satisfactory corrosion resistance^{2,3} and are being used for tanks and accessory equipment for the storage, transportation, and application of this type of fertilizer.

Carbon steel, although corroded to some extent by the nitrogen solutions, has been used for small storage and applicator tanks because of its relatively low price and availability; however, copper alloys and zinc are severely corroded by these solutions.² In the case of the complete-mix fertilizer solutions, both carbon steel and the chromium-nickel stainless steels have been used to some extent, but it has been reported that some of the materials that are satisfactory for use with the nitrogen solutions are not satisfactory for use with the complete-mix solutions.^{3,4}

Complete data on the suitability of various metals as constructional materials for tanks and other equipment for both types of liquid fertilizers are not available. Therefore, the present investigation was undertaken to obtain additional data.

Materials

The materials tested in this investigation included plain-carbon steels (AISI 1010 and 1020), chromium stainless steels (Types 502, 405, and 430), chromium-nickel stainless steels (Types 302, 304, 304L, and 316L), and aluminum alloys (3003-H14 and 6061-T6). The chemical compositions of these materials are listed in Tables 1 and 2. All of these materials were obtained from regular mill products and are representative of commercially available materials. Most of the materials were tested in two types of commercial fertilizer solutions: nitrogen fertilizer solutions supplied by the Nitrogen Division, Allied



D. C. VREELAND—Applied Research Laboratory, U. S. Steel Corporation, Monroeville, Pa. He received a BS from Antioch College and an MS in metallurgy from Ohio State University. Prior to joining U. S. Steel, Mr. Vreeland was with Westinghouse Electric Corporation, Electronic Tube Division, and Oak Ridge National Laboratory, where he conducted research on corrosion in liquid metals and fused salts. His present work deals primarily with the corrosion of stainless steel.



S. H. KALIN—Research Technologist, Chemical Metallurgy Division of the Applied Research Laboratory, U. S. Steel Corporation, Monroeville, Pa. For the past four years he has been engaged in the investigation of intergranular corrosion and stress corrosion of stainless steel, the evaluation of various steels in specific corrosives and studies of atmospheric corrosion of steels and metallic coatings. He is a member of NACE and the ASTM subcommittee on stainless steel in architectural application. Mr. Kalin received a BS in metallurgy from MIT in 1938.

Abstract

Laboratory corrosion tests were conducted on aluminum, carbon steel, chromium, and chromium-nickel stainless steels to evaluate their suitability as constructional materials for storage, transport, and applicator tanks for "nitrogen" and "complete-mix" liquid fertilizers. Two types of corrosion tests were conducted: (1) Partial immersion of small specimens of each material in each fertilizer solution, and (2) Simulated service tests in which small tanks fabricated of each of the test materials were partially filled with each of the fertilizer solutions. The amount and type of corrosion was evaluated by weight-loss determinations, thickness changes, pit-depth measurements, and metallographic examinations.

The results of the corrosion tests showed that in the nitrogen fertilizer solutions aluminum and several chromium and chromium-nickel stainless steels, were not attacked while carbon steel was attacked. In the complete-mix fertilizer solutions, only the chromium-nickel stainless steels were not attacked while aluminum, carbon steel, and three chromium stainless steels were attacked.

Service tests are being considered on carbon steel and some of the stainless steels that had satisfactory corrosion resistance in the laboratory tests. 434

Chemical and Dye Corporation, and complete-mix fertilizer solutions supplied by the Monsanto Chemical Company.

The compositions of the two nitrogen fertilizers, Nitrana (ammonia-ammonium nitrate solution), and Feran (ammonium nitrate solution) are given in Table 3 while those of the eight complete-mix solu-

*Submitted for publication April 16, 1956. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.



Figure 1—Apparatus used in two types of corrosion tests. At left is apparatus used in partial-immersion test and at right for tank test.

TABLE 1—Composition of Materials Used in Partial-Immersion Tests, Percent

MATERIAL	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Others
Carbon Steel	0.18	0.51	0.010	0.032	0.07	0.05	0.03	0.09	ND*	.....
Type 502	0.06	0.51	0.014	0.010	0.35	ND	0.36	5.2	0.48	.....
Type 405	0.05	0.85	0.017	0.015	0.57	0.06	0.25	12.5	0.06	0.21 Al
Type 430	0.08	0.47	0.028	0.025	0.32	0.08	0.24	17.1	ND	.....
Type 304	0.05	1.3	0.024	0.014	0.36	ND	9.0	18.9	ND	.....
Type 316	0.06	1.6	0.027	0.010	0.51	0.19	12.9	18.0	ND	.....
Aluminum... (3003-H14)	ND	1.15	ND	ND	0.20	0.14	ND	ND	ND	0.33 Fe, 0.02 Zn

*ND—Not determined.

TABLE 2—Composition of Materials Used in Simulated-Service Tank Tests, Percent

MATERIAL	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Others
Carbon Steel	0.08	0.37	0.006	0.030	0.01	0.05	0.02	0.01	0.01	.....
Type 502	0.07	0.41	0.020	0.018	0.30	ND*	0.17	5.1	0.52	.....
Type 405	0.06	0.56	0.023	0.13	0.43	ND	0.41	12.2	ND	0.21 Al
Type 430	0.06	0.45	0.023	0.014	0.60	0.12	0.24	17.0	ND	.....
Type 302	0.07	1.95	0.032	0.023	0.49	0.38	9.4	17.6	0.30	.....
Type 304L	0.02	0.89	0.020	0.027	0.62	0.18	10.3	18.9	ND	.....
Type 316L	0.02	1.66	0.024	0.019	0.51	0.18	12.9	17.7	2.10	.....
Aluminum (6061-T6)	ND	ND	ND	ND	0.5	0.3	ND	0.25	ND	0.96 Mg

*ND—Not determined.

tions are given in Table 4. The latter are designated by their nutrient content in weight percent. For example, 3-9-9 contains three percent nitrogen (N), nine percent phosphoric anhydride (P_2O_5), and 9 percent potash (K_2O). To reduce their corrosivity, the nitrogen solutions contain a proprietary inhibitor and the complete-mix solutions are formulated to a neutral pH by adjustment of the ratio of ammonia to P_2O_5 .

Test Methods

Most materials were evaluated by two types of corrosion tests: (1) Partial-immersion tests of small specimens in flasks containing the fertilizers, and (2) Simulated-service tests in which small tanks (about 600 milliliter capacity) of each material to be tested were fabricated by welding and then were partially filled with the fertilizer solution. Figure 1 shows the equipment used in the two types of corrosion tests.

For the partial-immersion tests 1-inch by 2-inch specimens were prepared from annealed sheets (usually about $\frac{1}{8}$ inch thick) of the materials investigated. Many of the specimens were tested in the welded condition in which case a heliarc weld was made without filler rod along one of the long edges of the specimen. The surfaces and edges of all specimens were prepared by belt grinding and then hand polishing with 120-grit emery paper. The specimens were then washed, degreased in acetone, dried, and weighed.

The carbon-steel specimens were activated by immersion for 3 seconds in 15 percent hydrochloric acid at 150 F. The other steel specimens were activated by immersing them in 5 percent sulfuric acid at 85 F and touching them with an iron wire until bubbles appeared on their surfaces. They were then rinsed in distilled water and quickly transferred to the test solutions which were contained in glass beakers or in stoppered glass bottles.

Each specimen was tested in a separate container and was suspended from a glass hook so that two-thirds of its length was immersed in the test solution: Only part of the specimen was immersed so that cor-

TABLE 3—Composition of "Nitrogen" Liquid Fertilizers, Weight Percent

MATERIAL	Feran*	Nitrana*
Ammonia, free.....	0	22.2
Ammonium nitrate.....	60.0	65.0
Urea.....	0	0
Water.....	40.0	12.8

* Feran and Nitrana are registered trade marks for products distributed by Nitrogen Division, Allied Chemical and Dye Corporation.

rosion could be observed in the liquid zone, vapor zone, and liquid-vapor interface.

In the case of the complete-mix solutions and the Feran solution, the test containers were stoppered glass bottles containing 800 ml and 150 ml of solution, respectively. The glass bottles were immersed in thermostatically controlled water baths at 135 F in the case of the complete-mix solutions and at 100 F in the case of Feran.

In the case of the Nitrana solution, the test containers were glass beakers containing 150 ml of solution. Because the latter solution contains about 20 percent free ammonia, the glass beakers were placed in a small pressure chamber to prevent loss of ammonia. The pressure chamber was then immersed in a thermostatically controlled water bath maintained at 100 F. All specimens were tested for 28 days except those immersed in Nitrana which were tested for 14 days. After removal from the test solutions, the specimens were cleaned to remove any corrosion products and then were weighed. The corrosion rate of each specimen was calculated from its loss in weight. All specimens were examined visually at a magnification of 5X to determine location and type of attack.

In the case of the simulated-service tests, the 600 ml capacity tanks fabricated by arc-welding from the metals to be tested were first pickled to remove welding scale. Weld rod of the same grade as the tank was used except in the case of the Type 430 and 302 tanks where Type 310 and 308 weld rods were used, respectively. A tank of each test material was then partially filled with 400 ml of each test solution, stoppered, and placed in a thermostatically

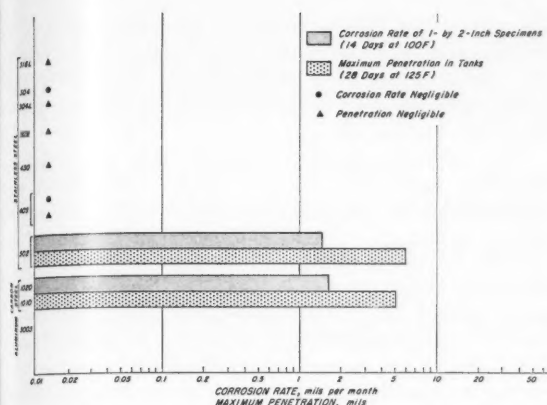


Figure 2—Corrosion rate and maximum penetration during 14 and 28 day tests in Nitrana fertilizer solution at 100 and 125 F.

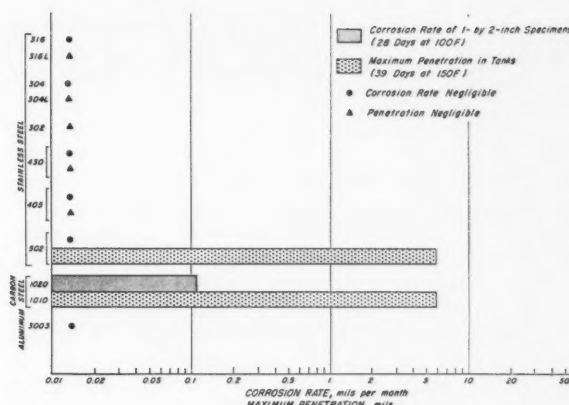


Figure 3—Corrosion rate and maximum penetration during 28 and 39 day tests in Feran fertilizer solution at 100 and 150 F.

TABLE 4—Composition of "Complete-Mix" Liquid Fertilizers, Weight Percent

	8-24-0*	3-9-9*	6-6-6* with Urea	6-6-6* with Ammonium Nitrate	6-6-6* with Uran†	10-10-5* with Urea	10-10-5* with Ammonium Nitrate	10-10-5* with Uran†
Nitrana*								
Ashydrous ammonia	9.79	3.67	2.45	2.45	2.45	4.08	4.08	4.08
75 percent phosphoric acid	44.64	16.74	11.16	11.16	11.16	18.60	18.60	18.60
Urea	0	0	8.80	0	4.48	14.67	0	7.47
Ammonium nitrate	0	0	0	11.57	5.60	0	19.28	9.34
Potassium chloride	0	14.54	9.70	9.70	9.70	8.08	8.08	8.08
Water	45.57	65.05	67.89	65.12	66.61	54.57	49.96	52.43
pH	6.6	6.6	6.8	6.3	6.5	6.9	6.2	6.5

* Nutrient content (N-P₂O₅-K₂O).

† Uran is the trade name for a commercially available nitrogen solution marketed by Nitrogen Division of Allied Chemical and Dye Corporation. Its composition is 44.3 weight percent ammonium nitrate, 35.4 weight percent urea, and 20.3 weight percent water.

TABLE 5—Results of Partial-Immersion Tests in Liquid Fertilizers at 100 to 135 F for 14 to 28 Days¹

FERTILIZER	CORROSION RATE*, MILS PER MONTH						
	Carbon Steel (AISI 1020)	Type 502	Type 405	Type 430	Type 304	Type 316	Aluminum (3003-H14)
Nitrana	1.6	1.5	<0.01	†	<0.01	†	<0.01
Feran	0.11	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6-6-6 (with ammonium nitrate)	0.66	0.49	<0.01	<0.01	<0.01	<0.01	1.18
6-6-6 (with ammonium nitrate)	0.31	0.68	<0.01	<0.01	<0.01	<0.01	2.16
6-6-6 (with Uran)	0.21	0.08	<0.01	<0.01	<0.01	<0.01	0.87
6-6-6 (with urea)	0.12	0.04	<0.01	<0.01	<0.01	<0.01	2.09
6-6-6 (with urea)	0.28	0.05	<0.01	<0.01	<0.01	<0.01	0.68
10-10-5 (with urea)	0.22	0.04	<0.01	<0.01	<0.01	<0.01	3.82
3-9-9	0.31	1.19	0.03	<0.01	<0.01	<0.01	2.06
8-24-0	0.14	<0.01	<0.01	<0.01	<0.01	<0.01	16.7

* Calculated from weight loss.

† Not tested.

¹ Tests in Nitrana were at 100 F for 14 days; tests in Feran were at 100 F for 28 days, and tests in other solutions were at 135 F for 28 days.

controlled water bath. The tests with the complete-mix fertilizers were conducted at 135 F for 28 days, those with Nitrana at 125 F for 28 days, and those with Feran at 150 F for 39 days. Temperatures as high as 150 F were used because temperature measurements made on liquid fertilizer in a tank car showed that on a sunny day the temperature of the vapor in the dome of the car was about 135 F. It seems probable that in the south or southwest portion of the country, temperatures in tank car domes might reach 150 F.

During the tests with the complete-mix fertilizers, the solutions in the tanks were changed twice a week to more nearly simulate actual service conditions. At the end of the test, the solutions were

drained from the tanks and the tanks were rinsed and dried. They were cut in half lengthwise, photographed, and then cleaned to remove corrosion products. They were examined with a low-power microscope at magnifications up to 20X and the amount of corrosion was determined by decrease in thickness and pit-depth measurements. Sections of weld and base metal cut from the liquid and vapor zones on walls of the tanks were examined metallographically.

Some stress-corrosion tests were conducted with horseshoe-type specimens in some of the fertilizers and others are now in progress. Because the tanks were fabricated by cold blanking the ends and cold forming the bodies, and because they were not stress relieved after welding, residual stresses were present. The tank tests therefore may be considered as stress-corrosion tests.

Results and Discussion

For clarity the results of each of the two types of corrosion tests in each of the two basic types of fertilizer solutions will be discussed separately.

Nitrogen Fertilizer Solutions

Partial-Immersion Tests. The corrosion rates as determined by weight loss of 1-inch by 2-inch specimens partially immersed in Nitrana or Feran are shown in Table 5 and Figures 2 and 3. These results show that Types 405 and 304 stainless steel and 3003-H14 aluminum were not measurably attacked by either of the two solutions, while carbon steel and Type 502 stainless steel were attacked. The attack on the latter two steels was much greater in Nitrana

(1.6 and 1.5 mils per month, respectively) than in Feran (0.11 and <0.01 mils per month, respectively). Types 430 and 316 were not attacked by Feran, but were not tested in Nitrana.

It should be pointed out that the corrosion rates were calculated on the basis of corrosion over the entire surface of each specimen. However, the corrosion on the carbon steel and Type 502 was confined to a relatively small portion of each specimen, such as the liquid-vapor interface, whose area could not be accurately measured. Therefore, the actual depth of attack was much greater than that indicated by the calculated corrosion rate. This was confirmed by the tank tests discussed later in which the maximum depth of attack was determined by thickness changes and pit-depth measurements.

Because the susceptibility of carbon steel to stress corrosion by aqueous ammonium nitrate solutions is well-known,⁵ small specimens of each material were bent to form horseshoe-type stress-corrosion specimens and immersed in each of the two solutions for 14 to 28 days at 100 F. These were examined for evidence of stress corrosion after exposure but no cracks were observed. However, as will be discussed later, stress-corrosion cracks were observed on the bottom of the carbon-steel tank tested with Feran at 150 F. The reason for the difference in the behavior of the carbon-steel specimens and the carbon-steel tank with respect to stress corrosion is not known, but is being investigated at present. It is possible that differences in stress level, testing temperature, composition, or microstructure may be responsible for the difference in behavior. Additional stress-corrosion tests are being conducted with bent-beam and Olsen-cup type specimens, some of which are being tested in alternate immersion.

Tank Tests—The maximum depths of attack resulting from exposure of small tanks to Nitrana at 125 F for 28 days or Feran at 150 F for 39 days are shown in Table 6 and Figures 2 and 3. As would be expected from the results of the partial-immersion tests, Types 405, 430, 302, 304L (low-carbon Type 304), and 316L (low-carbon Type 316) stainless steel and 6061-T6 aluminum were not measurably attacked by either solution while carbon steel and Type 502 stainless steel were attacked. The attack on the latter two steels in Nitrana was general in nature and occurred mainly at the liquid-vapor interface and in the vapor zone. The maximum depth of attack on both steels was about the same, 6 mils on Type 502 and 5 mils on carbon steel. The attack on the carbon-steel and Type 502 tanks in Feran was mainly pitting and occurred both in the vapor zone and the liquid zone. Both steels were pitted to the same depth, 6 mils.

The results of metallographic examination of specimens cut from

the vapor and liquid zones on the sidewalls of the tanks after test are shown in Table 7. No attack was observed in any of the Types 302, 304L, and 316L specimens, even in the heat-affected zones near the welds.

The carbon-steel tanks tested with the nitrogen fertilizer solutions, which contain ammonium nitrate, were attacked intergranularly. This type of attack is typical of that observed on mild steel in nitrate solutions by other investigators^{5,6} and is believed by Parkins⁶ to be caused by distortion at the grain boundaries which makes the grain boundaries anodic to the grains and susceptible to corrosion. This theory has been used by Parkins to explain the stress corrosion of mild steel in nitrate solutions when the material is highly stressed. As mentioned previously, intergranular stress-corrosion cracks were observed on the bottom of the carbon-steel tank tested with Feran. It is believed that the stress-corrosion cracking but not the intergranular attack could have been prevented by stress relieving the tank at 1100 F.

No cracking was encountered with this steel in Nitrana or with any of the other steels in Nitrana or Feran.

Complete-Mix Fertilizer Solutions

Partial-Immersion Tests. Types 430, 304, and 316 stainless-steel specimens were not measurably attacked during 28 days partial immersion in any of the eight complete-mix liquid fertilizers. The results of these tests are shown in Table 5 and, in addition, the results in four of the eight fertilizers are presented graphically in Figures 4 to 7. Type 405 was measurably attacked only in 10-10-5 (with Uran) and 3-9-9 solutions while Type 502 was attacked in all the complete-mix fertilizers except 8-24-0. Carbon steel and 3003-H14 aluminum were attacked in all eight solutions.

The greatest corrosion of the carbon-steel specimens occurred in the 6-6-6 and 10-10-5 solutions made up with ammonium nitrate (corrosion rates of 0.66 and 0.31 mils per month, respectively) and the least occurred in the 10-10-5 (with Uran) and the 8-24-0 solutions (0.12 and 0.14 mils per month, respectively). Generally, most of the severe attack on

TABLE 6—Results of Tank Tests With Liquid Fertilizers at 125 to 150 F for 28 to 39 Days¹

Fertilizer	Maximum Depth of Penetration*, Inches							Aluminum (6061-T6)
	Carbon Steel (AISI 1010)	Type 502	Type 405	Type 430	Type 302	Type 304L	Type 316L	
Nitrana.....	0.005	0.006	None	None	None	None	None	**
Feran.....	0.006	0.006	None	None	None	None	None	**
6-6-6 (with ammonium nitrate).....	0.032	0.025	None	None	None	None	None	0.010
10-10-5 (with ammonium nitrate).....	0.036	0.042	0.008	None	None	None	None	0.001
6-6-6 (with Uran).....	0.014	0.038	0.036	0.011	None	None	None	0.004
10-10-5 (with Uran).....	0.020	0.015	0.006	None	None	None	None	0.009
6-6-6 (with urea).....	0.008	0.022	0.050 ²	0.006	None	None	None	0.001
10-10-5 (with urea).....	0.010	0.008	0.020	None	None	None	None	0.004
3-9-9.....	0.010	0.020	0.050 ²	0.034	None	None	None	0.004
8-24-0.....	None ³	None	None	None	None	None	None	0.048

* Determined by pit depth and thickness measurements.

** Not tested.

¹ Tests in Nitrana were at 125 F for 28 days, tests in Feran were at 150 F for 39 days, and tests in other solutions were at 135 F for 28 days.

² Perforated.

³ No measurable penetration but thin film of corrosion product.

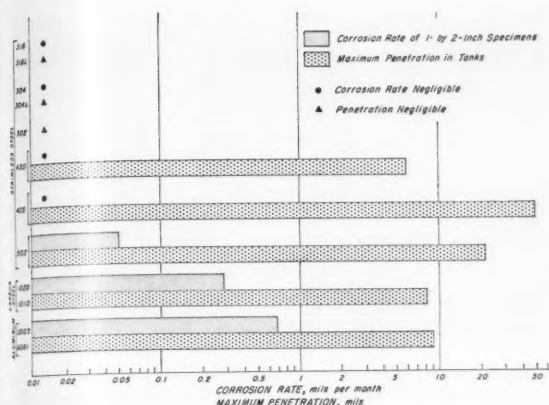


Figure 4—Corrosion rate and maximum penetration during 28 day tests in 6-6-6 (with urea) fertilizer solution at 135 F.

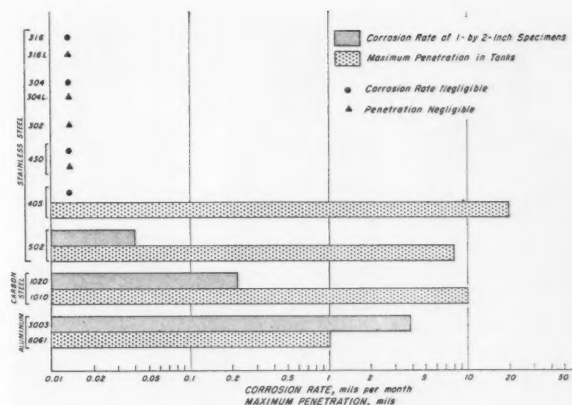


Figure 5—Corrosion rate and maximum penetration during 28 day tests in 10-10-5 (with urea) fertilizer solution at 135 F.

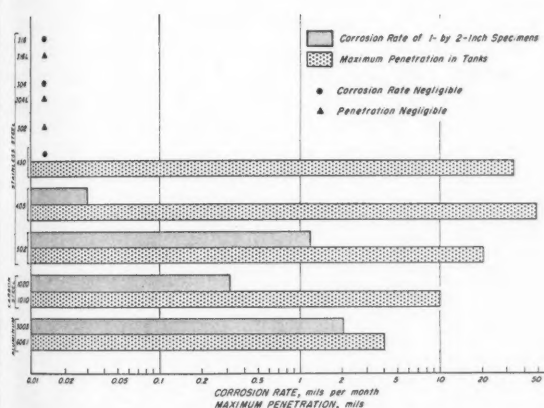


Figure 6—Corrosion rate and maximum penetration during 28 day tests in 3-9-9 fertilizer solution at 135 F.

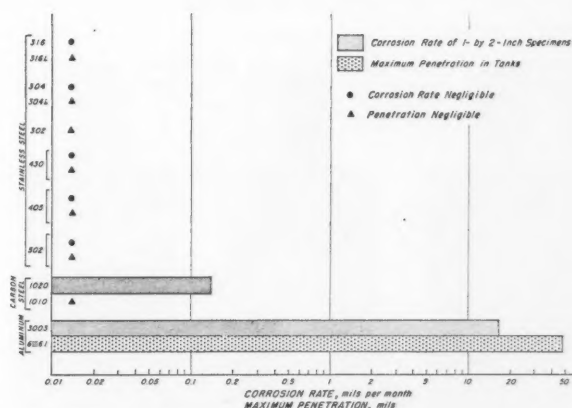


Figure 7—Corrosion rate and maximum penetration during 28 day tests in 8-24-0 fertilizer solution at 135 F.

TABLE 7—Results of Metallographic Examination of Tanks Tested With Liquid Fertilizers

FERTILIZER	NATURE OF ATTACK							
	Carbon Steel	Type 502	Type 405	Type 430	Type 302	Type 304L	Type 316L	Aluminum (6061-T6)
Nitram	Intergranular and general	General	None	Intergranular (HAZ)*	None	None	None	**
Peran	Intergranular and general; cracks on bottom	General and pitting	None	None	None	None	None	**
6-6-6 (with ammonium nitrate)	General and pitting	General and pitting	None	Intergranular (HAZ)*	None	None	None	Pitting
10-10-5 (with ammonium nitrate)	General and pitting	General and pitting	Pitting	Intergranular (HAZ)*	None	None	None	General
6-6-6 (with Uran)	General and pitting	General and pitting	Pitting	Intergranular (HAZ)*	None	None	None	Pitting
10-10-5 (with Uran)	General and pitting	General and pitting	Pitting	Intergranular (HAZ)*	None	None	None	Pitting
6-6-6 (with urea)	General and pitting	General and pitting	Pitting	Intergranular (HAZ)*	None	None	None	Pitting
10-10-5 (with urea)	General and pitting	General and pitting	Pitting	Intergranular (HAZ)*	None	None	None	General and pitting
3-9-9	General and pitting	General and pitting	Pitting	Intergranular (HAZ)*	None	None	None	Pitting
8-24-0	General	General	None	Intergranular (HAZ)*	None	None	None	General

* Heat-affected zone near weld.

** Not tested.

the steel specimens was located on the portion of the specimens in the vapor zone.

The greatest attack on the aluminum specimens occurred in the 8-24-0 solution (corrosion rate of 16.7 mils per month) and the least occurred in the 6-6-6 solutions (0.68 to 1.2 mils per month). It is interesting to note that the corrosion of aluminum was greatest in the solution containing the highest concentration of phosphoric acid. Unlike the steel

specimens, the attack on the aluminum specimens was fairly uniform. The greatest attack was general in nature and occurred in the liquid zone although some pitting attack was observed in the vapor zone.

As in the case of the partial-immersion tests in the nitrogen fertilizers, when corrosion occurred the major attack was confined to a relatively small portion of the specimens. Thus the corrosion rates, which were calculated on the basis of the entire sur-



Figure 8—Photograph showing inside of three Type 302 stainless-steel tanks after 28 day test with complete-mix fertilizer solutions at 135 F. Tanks, from left to right, contained 10-10-5 (with ammonium nitrate), 3-9-9, and 8-24-0, respectively.

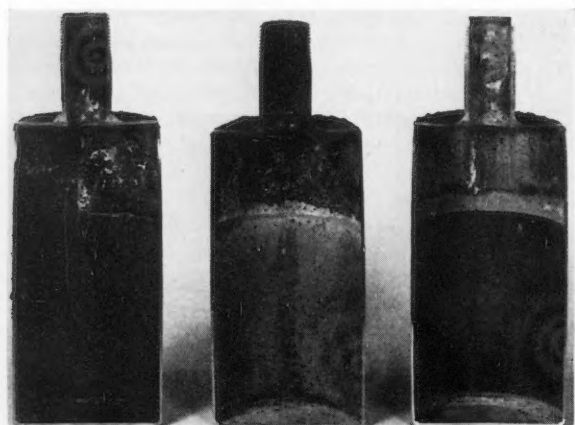


Figure 9—Photograph showing inside of the AISI 1010 carbon-steel tanks after 28 day test with complete-mix fertilizer solutions at 135 F. Tanks, from left to right, contained 6-6-6 (with urea), 6-6-6 (with ammonium nitrate), and 8-24-0, respectively.

face of the specimens, do not truly represent the actual rates of penetration which in most cases were considerably greater than the corrosion rates. The results of the tank tests confirmed this.

Tank Tests. The results of the tank tests with all the complete-mix fertilizers are shown in Table 6 and the results with four typical ones are shown graphically in Figures 4 to 7. Only the Types 302, 304L, and 316 L tanks were unattacked by all of the complete-mix fertilizer solutions. The excellent condition of three representative Type 302 tanks after testing is shown in Figure 8. These tanks were not cleaned before photographing and their condition is typical of that of all the Types 302, 304L, and 316L tanks tested in the complete-mix fertilizers.

The carbon-steel tanks and the 6061-T6 aluminum tanks were attacked by all of the solutions. The Type 502 tanks were attacked by all the solutions except 8-24-0, while the Type 405 tanks were attacked by all the solutions except 6-6-6 (with ammonium ni-

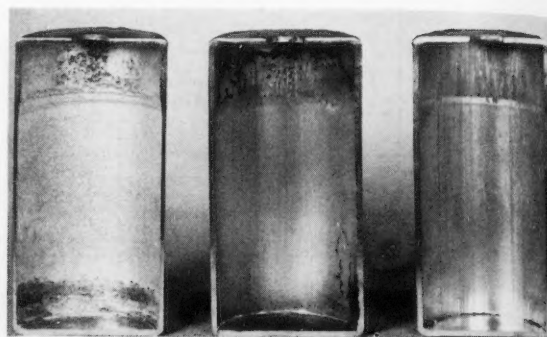


Figure 10—Photograph showing inside of three 6061-T6 aluminum tanks after 28 day test with complete-mix fertilizer solutions at 135 F. Tanks, from left to right, contained 8-24-0, 6-6-6 (with Uran), and 10-10-5 (with urea), respectively.

trate) and 8-24-0; however, the Type 430 tanks were only attacked by the 6-6-6 (with urea), 6-6-6 (with Uran), and 3-9-9 solutions except as discussed later.

The heaviest attack on the carbon-steel and the chromium stainless-steel tanks with but few exceptions occurred in the vapor zone and was of the pitting type. Voluminous corrosion products formed in the vapor zones coincident with the attack. The condition of three of the carbon-steel tanks after test but before cleaning is illustrated by the photograph in Figure 9. Voluminous corrosion products are evident on the tanks which had contained 6-6-6 (with urea) or 6-6-6 (with ammonium nitrate) solutions. These corrosion products are typical of those found on most of the carbon-steel tanks. Pits from 8 to 32 mils deep were observed when the corrosion products were removed from these two tanks. Only a very thin layer of corrosion product is evident on the tank which contained 8-24-0 solution. When this was removed no pitting was observed.

In the case of the aluminum tanks, the attack occurred mainly in the liquid zone and was general in nature; however, some severe pitting occurred in both the vapor zone and the liquid zone. Figure 10 shows the various types of attack that were observed on the aluminum tanks. Severe general attack (maximum penetration of 48 mils) is evident in the liquid zone on the tank tested in 8-24-0, severe pitting is noticeable in the liquid and vapor zones on the tank tested in 6-6-6 (with Uran), and very light general attack as indicated by brightening of the surface is evident in the liquid zone of the tank tested in 10-10-5 (with urea).

Cracks were observed in the heat-affected zones near the welds on the Type 430 tanks tested in the 10-10-5 solutions, 6-6-6 (with ammonium nitrate), and 8-24-0. Metallographic examination showed intergranular attack and an intergranular network of martensite in portions of the heat-affected zone on Type 430 tanks tested in all the complete-mix solutions. It is believed that some of the cracks are related to the formation of martensite at the grain boundaries during the welding operation⁷ and that others are related to the intergranular attack which is believed to be the result of grain boundary precipitation of a carbide or nitride phase.⁸ The brittleness of Type 430 welds may be alle-

ated by annealing at 1400 to 1500 F after welding or by use of a modified Type 430 alloy containing enough titanium to combine with all the carbon in the alloy and prevent the formation of martensite.⁷ These procedures were not tried but should be investigated before Type 430 is considered for the construction of welded tanks for fertilizer solutions.

No cracks or intergranular attack were observed with any of the other materials.

The attack on the carbon-steel and chromium stainless-steel tanks was usually more severe than that observed on the partial-immersion test specimens. In fact, although no attack was observed on the Type 405 specimens in two of the 6-6-6 solutions and two of the 10-10-5 solutions, severe pitting, and in one case perforation, was observed in the tanks containing these solutions. It is believed that the greater severity of the attack on the tanks resulted from the complete change of the fertilizer solutions in the tanks twice weekly during the test. Not only did this practice bring fresh corrodent to the tanks, but it periodically brought a fresh supply of oxygen into the tanks thus making the conditions more corrosive. The solutions in which the specimens were immersed were not changed during the test.

Conclusions and Recommendations

The results of laboratory corrosion tests of about 1-month duration at 100 to 150 F showed that in the nitrogen fertilizer solutions, Types 405, 302, 304, 304L, 316, and 316L stainless steel and 3003-H14 aluminum were not attacked while AISI 1010 or 1020 carbon steel and Type 502 were attacked. In the complete-mix fertilizers, only Types 302, 304, 304L, 316 and 316L stainless steel were not attacked while 6061-T6 and 3003-H14 aluminum, AISI 1010 and 1020 carbon steel, and Types 502 and 405 stainless steel were attacked. Although Type 430 stain-

less steel was measurably attacked in only 6-6-6 (with Uran), 6-6-6 (with urea), and 3-9-9, intergranular attack and in some cases cracks were observed in the heat-affected zone near the welds when Type 430 tanks were tested with all the fertilizers except Feran.

These findings indicate that the 12 percent chromium stainless steels similar to Type 405, the chromium-nickel stainless steels, and aluminum should be suitable as constructional materials for tanks for nitrogen liquid fertilizers and the chromium-nickel stainless steels should be suitable for tanks for complete-mix fertilizers. However, service tests should be conducted with these materials before any particular alloy is generally adopted for this application.

Welded Type 430 tanks may be suitable for use with the nitrogen fertilizers and some of the complete-mix fertilizers if the tanks are properly heat treated after welding to remove stresses and eliminate susceptibility to intergranular attack of the heat-affected zone.

Because carbon steel was not appreciably attacked by 8-24-0 in the tank test, it may be suitable for use with this fertilizer solution and should be service tested.

References

1. R. P. Langguth, et al. *Agricultural and Food Chemistry*, **3**, No. 8, 656-662, (1955) August.
2. Nitrogen Division, Allied Chemical and Dye Corporation, "Arcadian Nitrogen Fertilizer Solutions for Direct Application," 1954.
3. C. F. Schreiber. *Corrosion*, **11**, No. 3, 119t-130t, (1955) March.
4. A. V. Slack. *Agricultural and Food Chemistry*, **3**, No. 7, 568-574, (1955) July.
5. J. A. Jones. *Trans Faraday Soc.*, **17**, 102-109 (1921).
6. R. N. Parkins. *J. Iron and Steel Inst.*, **172**, 149-162, (1952) Oct.
7. Anonymous. *Industry and Welding*, P. 58, (1952) Dec.
8. R. A. Lula, A. J. Lena, and G. C. Kiefer. *Trans. American Soc. for Metals*, **46**, 197-223 (1954).

**Any discussions of this article not published above
will appear in the December, 1956 issue.**

Use of Baked Coatings in the Oil, Chemical and Processing Industries*

By G. J. DUESTERBERG

Introduction

SINCE THE end of World War II, plastics have become more and more recognized as practical and economical materials of construction in industries handling corrosive products. These plastics may be in the form of molded or extruded shapes, rigid sheets, pliable sheet linings or plastic coatings. In order not to be too general, this paper will be limited to thermosetting or baked coatings as related to the oil, chemical and processing industries.

The most common of the baked or thermosetting coatings undoubtedly are the phenolics which are derived from phenols and aldehydes. The phenolics are applied, usually by spray, in a soluble and fusible state. After the desired film thickness is attained, the phenolic is cured or polymerized, usually by the addition of heat, to an insoluble and fused state.

In baking at the recommended temperature, a further check on a complete cure is assured inasmuch as a very definite color change occurs after polymerization has taken place. Until the thermosetting resins are polymerized or cured, they remain soluble and unfused thermoplastic resins and do not provide the excellent chemical resistance and physical characteristics of the polymerized resin. To the author's knowledge, the best method of ensuring polymerization is by baking properly until the desired color change has taken place.

After curing, the baked phenolic is reddish-brown in color and has a hard, smooth, glass-like surface. It has excellent chemical resistance over a wide range of acids and hydrocarbons at elevated temperatures and considering its hardness it is amazingly resilient. It provides excellent adhesion when confined within the range of 5-6 mils in thickness. (Extreme care must be taken in phenolic application as films a few mils in excess of this thickness may crack and lose adhesion.)

The recent introduction of epoxy resins has permitted a marriage with the phenolics which provides a modification of the phenolic formulation. This modification enhances the physical characteristics of the phenolics and at the same time still provides the necessary chemical resistance to many chemical conditions encountered. Although modification of the phenolic sacrifices resistance to higher concentrations of acid and some solvents, it provides excellent resistance to caustics and high pH chemicals that the phenolics will not withstand. The modified baked



G. J. DUESTERBERG is president of Plastic Applicators, Inc., Houston, Texas, a company which he organized in November, 1945. He is engaged in the application of baked plastic coatings and rubber linings to tubular goods, tanks and equipment to serve the oil, chemical and food processing industries of the Gulf Coast and Southwest. Mr. Duesterberg received a BS degree in 1940 from New Mexico School of Mines, Socorro, New Mexico.

Abstract

Baked coatings have three primary uses in the oil, chemical and processing industries: (1) To combat corrosion (2) To protect finished products from iron contamination (3) To eliminate growth of solids such as synthetic polymers, scale, salt and paraffin. Case histories are given to show how baked coatings have been used in industry to accomplish these tasks. 5.4.5

phenolic will permit a greater film thickness and has a much higher degree of flexibility than the phenolic.

Before a baked coating is selected for a given service condition, it should be thoroughly tested in actual operating conditions, if there is any doubt about its resistance. Through experience and with the assistance of available resistance data, it is safe to assume that the coating will withstand certain simple conditions at ambient temperatures. However, if the problem is at all complex, the coating should be tested. Test coupons are satisfactory for an initial screening test, but a coated spool piece or a fitting should be installed in the system before a final decision is made.

Principal Uses

The principal uses of baked coatings can be broken down into three categories: prevention of corrosion, protection against product contamination and reduction of growth of solids.

Corrosion Protection

In selecting a baked coating to combat corrosion, the type and severity of corrosion should be considered. The most economical performance can be gained in coating equipment that is generally considered expendable (i.e., equipment that is in the

* Submitted for publication November 16, 1955. A paper presented at a meeting of the South Central Region, National Association of Corrosion Engineers, Houston, Texas, October 18-21, 1955.

corrosion range where the operator cannot justify high first cost expenditures for expensive alloys and has the alternative of taking the corrosion loss and replacing at the end of a year or several years, or utilizing a protective coating to extend the life of his equipment.) Some case histories will help clarify this. A case in point concerns a synthetic rubber plant that had a vessel operating under pressure containing 60 percent sulfuric acid at a slightly elevated temperature. After four years of operation, this vessel was inspected and was found to have reached its corrosion allowance. In an attempt to save the vessel it was coated with baked phenolic. After an additional four years of operation with minor maintenance, the vessel and coating was still in good condition. The replacement cost of this vessel would have been approximately \$10,000 and the coating cost was approximately \$2,500. The economics of this application, therefore, is obvious.

Several styrene plants in the Gulf Coast area handling Ethyl Benzene and aluminum chloride had a high mortality rate with steel piping and centrifugal pumps. Ultimately all piping, valves, tanks and pumps were coated with baked phenolic; their replacements are now down to a minimum. In another instance a copper chloride treater at one of the Gulf Coast refineries was showing severe corrosion after a period of use. The vessel was badly corroded and severely pitted and would not have been suitable for coating with the straight phenolic. Instead it was coated with modified baked phenolic. Upon examination after six months operation, the coating was found to be in excellent condition and no additional corrosion had taken place.

A unique application of the baked phenolic is in the coating of lubricated plug valves. The plug is machined and approximately .016 inches is taken off the diameter to allow for the coating. After the valve has been coated, the plug is lapped into the body to effect a tight seal. The greatest advantage of coated plug cocks is the elimination of sticking of the plug in the body. They are used mostly in sulfuric acid, sour crude, sour benzene, etc.

In the oil production industry baked coatings are finding wide usage in gas lift wells, gas condensate wells, salt water disposal and water flood systems, high pressure sweet crude wells, sour crude wells and gathering lines. This includes tubing, casing, line pipe, gas lift mandrels, valves and other miscellaneous equipment used in oil production.

Perhaps the widest application for coated pipe is in water-dependent type corrosion, and more specifically in gas lift wells and flowing oil wells, making a high percentage of water. Baked coatings provide a very economical solution to this severe corrosion problem. In many cases, this is the only solution to the problem.

It is the author's opinion that the baked modified phenolic coating has a tremendous future in the oil production industry. Because of the chemical conditions encountered in the oil production industry and because of the greatly improved physical characteristics of this coating over the straight phenolic, indications are that applications of coated pipe may

be expanded. Recently a 6000 foot string of tubing coated with a modified phenolic material was inspected. This material had been installed in a gas lift well producing a large volume of water with sand. A sand bridge occurred in this tubing and an attempt was made to break it using wire line jars. After several hours work with jars, it was deemed unsuccessful and a pulling unit was moved in to remove the tubing. This pipe was inspected with an internal optical inspection instrument to check the condition of the coating from a mechanical damage standpoint. Careful examination of the area where the jars were working showed no evidence of mechanical damage, whereas experience has shown that under the same conditions, the straight phenolic coating would have been severely damaged.

Another interesting example of the possible physical advantage of the modified phenolic is the following case history. Four test joints of coated tubing were inserted at random in a regular string of fracturing tubing. They were coated with a modified phenolic and were used in the following applications:

1. Three sand frac jobs with a total of 30,000 gallons of oil and 60,000 pounds of sand at 12 to 18 barrels per minute.
2. Two acid frac jobs with a total of 15,000 gallons of jelled acid and 22,000 pounds of sand.
3. Two acid jobs with a total of 7,000 gallons of regular acid.

Uncoated steel tubing has an expected life of 5 to 10 frac jobs. A recent inspection indicated only a mil of modified phenolic had worn in the service mentioned.

Improved coating materials and application techniques are rapidly providing the producing industry with lowest cost equipment and maintenance insurance of any of the known corrosion control methods.

Protection Against Product Contamination

The second category of principal uses for baked coatings is the protection of finished products from iron contamination by coating the process equipment. In today's competitive market, finished products must be protected against iron pickup because the producer may be faced with a penalty or possibly rejection of product due to the product being off specification. The phenolic is odorless and will not impart off-taste or off-color to food or beverages. It is one of the most popular protective coatings used by the brewing and distilling industries for their fermenting and storage tanks. Other important uses for the baked phenolic coating in this category are finished product storage tanks, process lines, tank cars and tank trucks. Some of the products protected by baked phenolics include acetone, ketone, alcohols, aviation gasoline, lube oils, etc. In addition to this many storage bins for storage of dry synthetic resins are coated with phenolics.

Reduction of Growth of Solids

The third category where baked phenolics are

widely used is coating of equipment to eliminate growth of solids such as synthetic polymers, scale, salt and paraffin. An example of the occurred when a refinery in the Sabine River area was circulating Sabine River water as cooling water through the tubeside of their ammonia condensers. Growth of scale was rapid and three condensers were in use. Because of the growth of scale, it was necessary to rotate cleaning of the condensers with the result that at least one of the three condensers was continually out of service for cleaning. The tube bundle from one of the condensers was coated internally and gave continuous service for one year and upon inspection was found to be clean and free of scale. The initial heat exchange efficiency loss was approximately 10 percent. After a few weeks operation, however, the efficiency was greater than the uncoated bundle and remained constant, whereas the efficiency of the uncoated bundle became increasingly lower until it was necessary to shut down for re-cleaning.

One of the widest uses for the baked phenolic coating is in tubing, flow lines, submarine lines and sucker rods coated for paraffin control. Coated pipe has provided a very effective and economical solu-

tion to this production problem. In about 98 percent of the installations of coated pipe, paraffin deposition is completely eliminated.

Design for Coatings

Some mention should be made in this paper of equipment design and surface preparation. As a result of the combined efforts of the corrosion engineer and the applicator, tremendous strides have been made in designing and preparing equipment to permit a good coating job. However, there is still an abundance of equipment that is earmarked for coating that does not receive proper engineering attention before fabricating. As a general rule, the requirements are few and simple; they include smooth continuous welding, flanged connections wherever possible, sharp edges broken to a slight radius, elimination of weld splatter and correction of normal surface imperfections.

Proper evaluation of the coating material used, a smooth surface for coating and finally a good continuous coating film will provide the industry with trouble-free equipment that will render satisfactory economical service through the years.

*Any discussions of this article not published above
will appear in the December, 1956 Issue.*

Properties, Specifications, Tests And Recommendations for Coal Tar Coatings*

Part 1—Hot Applied Coatings

By W. F. FAIR, JR.

Introduction

THERE HAS BEEN much misinformation appearing in current literature indicating general misunderstanding about coal tar coatings and their outstanding properties. This article is written to provide up-to-date information so as to acquaint corrosion engineers with recent developments in the field of coal tar coatings and to suggest proper types of specifications and applications for different coating combinations for the various service environments encountered.

It should be understood that bituminous materials as a class have such low water absorption characteristics and high electrical resistivities that complete comparative evaluations by technically satisfactory performance tests may take years of examination under simulated service conditions. Obviously these tests cannot be run for every project under consideration. The practical approach to the problem is to subject standard materials to long term performance tests to determine the ranges of such important properties as water absorption, water vapor transmission, oil spillage resistance, electrical resistivity, dielectric strength, and the like. Laboratory tests then should be incorporated in the specifications to provide batch reproducibility of materials insofar as physical properties are concerned, depending for satisfactory performance upon these specifications and the assurance that the coating belongs to a previously approved class, as represented. From the long-term tests, the assurance that the material is a suitable coal tar type of known previous good service and from the required physical properties provided by the specification tests, satisfactory performance of the coating may be confidently expected.

It should be noted that the commonly used coating specification tests provide no measure of quality if the nature of the coating is unknown.

Historical

Coal tar coatings may be divided into "Hot" and "Cold" applied types. The former have a long history of satisfactory performance under unusually severe conditions. For many years hot applied coal tar enamels have been used to protect the internal surfaces of iron and steel ships. Such surfaces are inner

W. F. FAIR, JR. is coating consultant in the Tar Products Division of Koppers Company, Inc., Verona, Pennsylvania. He received an AB from Harvard College and an MS and PhD in chemistry from Columbia University. His past experience includes research work for the Barrett Division of Allied Chemical and Dye Corporation, several years as Professor of Chemistry at Manhattanville College in New York City, and Senior Fellow at Mellon Institute on a Koppers Company Fellowship. For 10 years he supervised coatings development work of the Tar Products Division of Koppers Company at their Westfield, New Jersey, Laboratory. Dr.

Fair served as president of the Society of Rheology from 1945 to 1949, receiving the Bingham Medal in 1950, and was on the Board of Governors of the American Institute of Physics from 1945 to 1951. In March, 1956 he became president of NACE. Previously he had been chairman of the New York Metropolitan Section, member of the Board of Directors, and vice-president.



Abstract

Fundamental properties, long-term service characteristics, and specification writing and testing for various kinds of hot applied coal tar enamels are described. Emphasis is directed to the importance of long-term testing of coating types previously found to perform satisfactorily in service in various environments over long periods of time. A brief history of the use of hot applied coal tar coatings also is given.

Technique of application and a list of commonly used types of pipe coating are given. Data are tabulated for eight plasticized and seven unplasticized enamels with respect to softening point, penetration, percent ash, specific gravity, high temperature sag and low temperature crack. Water absorption rates are plotted for several pipe line enamels. On other graphs the relationship between rate of shear and shearing stress is shown for a number of roofing pitches. Electrical resistivity, soil stress resistance, and oil spillage resistivity are discussed in connection with coal tar enamels.

5.4.5

bottoms, tank tops, boiler and engine foundations, fore and aft peak tanks, coal bunkers, under tile or cement deck coverings, chain lockers, and similar surfaces which are either inaccessible after construction or wet and damp so much of the time that repainting is impractical without dry docking the vessel. Coal tar enamels have been used for such applications for approximately 100 years. They also have been used extensively for dry docks. One example of extremely good performance was recorded

*Submitted for publication June 28, 1955.

on a dock built in England in 1892 and scrapped in 1938. The enamel was reported to be in perfect condition after 46 years service, under the severe corrosive environment of alternately wetting with sea water and drying in the atmosphere.

Another dry dock, "The Dewey," was built at Sparrows Point in 1905 and towed to the Philippines. Upon inspection before the fall of Manila in World War II when the dock was 35 years old, it was reported that the enamel was still in excellent condition.

In more recent years, enamels have been used for other types of installations where heavy protective coatings were needed to withstand severe corrosion conditions. In 1913 enamel was used on the interior surfaces of a penstock for an hydroelectric company. Twenty-six years later inspections indicated that the coating was still satisfactory and exhibited no tubercles, blisters, or rust. Enamels and cold applied coal tar coatings have given exceptional service performance on penstocks and lock gates of the Panama Canal ever since operations commenced.

A test application of enamel was made by one of the largest cities in the United States. It was considered sufficiently satisfactory six years later to call for the specification of enamel for the interior and exterior surfaces of large diameter steel water pipe virtually throughout the whole extensive water transmission and distribution system of this city.

Many other water and sewer pipe line systems all over the country may be referred to in connection with the historical development of enamel coatings.

In the period 1926 to 1930, engineers specified enamel coatings for many of the oil and natural gas pipe lines built in that period. Since then, coal tar enamel coatings have been used extensively to protect such lines against soil corrosion.

Several years ago Kelly¹ reported that half of the pipe in service was protected with some form of coating and that 80 percent of the coated pipe was protected with a coal tar coating.

In 1945 Stirling² wrote on the economics of corrosion mitigation of underground pipe lines, emphasizing the savings to be expected by proper design and choice of coatings.

In his excellent papers on control of pipe line corrosion, Mudd³ describes methods of corrosion investigation with detailed examples, and of making line current and soil surface potential surveys. In discussing corrosion control, Mudd points out the

desirability of the utilization of cathodic protection and the best methods of installing cathodic protection. He concludes that counter-current protection in combination with coating constitutes the most economical and effective means of giving pipe lines their required service life.

Current preference for coal tar enamel coatings in the gas industry is demonstrated by results of a survey published in 1953.⁴

Application and Types

The coal tar enamels should be applied to clean surfaces and the surface should be primed with an appropriate recommended cold applied coal tar material before applying the molten hot enamel. Simultaneously with the application of the hot enamel, a spiral wrapping of a coal tar saturated asbestos pipe line felt or of glass fiber of suitable thickness or both, is applied to reinforce or shield the enamel. Special machines have been developed that ride the pipe to clean and apply the priming solution and to apply hot enamel and wrappers.

The enamels applied are of two general types, plasticized and unplasticized. The former has a wider service temperature range and is preferred over most of the country; the second type is usually specified where there is little danger of encountering sub-freezing temperatures. An intermediate type is preferred by some engineers.

In a paper presented at the 1951 Annual South Central Regional Meeting of NACE, N. T. Shideler of Pittsburgh Coke & Chemical Co. presented the data given in Table 1 to indicate the various trade names of enamels available in these three grades.

After application the coating and wrapping is tested by a holiday detector, an electric device which is moved along the coated pipe after cooling, to pick up any missed spots, pinholes, or holidays. Such weak spots after detection are then repaired before the pipe is subjected to regular service.

A large amount of steel pipe is coated in stationary yards. In such cases more variation may be possible because different techniques may be set up or changed as required. In one method of application the revolving pipe progresses past a fixed enamel delivery spout and wrapper spindles. Alternatively the coating system may be applied by rolling rig.

TABLE 1—Commercial Coatings

MANUFACTURER	Narrow Range Enamel	Moderate Range Enamel	Wide Range Enamel
Barrett Company.....	180-190 F Pipe line 190-200 F Pipe line	Millwrap ²	Waterworks
Koppers Company.....	XXH Enamel XXH Free Flowing	Bitumastic ¹ No. 2	Bitumastic ¹ 70B Bitumastic ¹ 70B Free Flowing
Reilly Tar & Chemical Company.....	Pipe Line Enamel		230 degree Enamel
Hill Hubbell Company.....		Biturine ² Aqualine ²	
Pittsburgh Coke & Chemical Company.....	Standard	Modified	Plasticized

¹ Registered Trademark of Koppers Company, Inc.

² Trademarks of other Companies.

TABLE 2—Yard Coating Combinations

DESIGNATION	Enamel Thickness and Wrapper
Specification No. 1	Primer—Hot applied enamel $\frac{1}{16}$ inch to $\frac{3}{32}$ inch thick, wrapper of asbestos pipe line felt or glassfiber wrapper, and Kraft paper.
Specification No. 2	Primer—Hot applied enamel $\frac{1}{16}$ inch thick to $\frac{3}{32}$ inch thick, wrapper of asbestos pipe line felt or glassfiber wrapper, hot applied enamel $\frac{1}{16}$ inch thick and Kraft paper.
Specification No. 3	Primer—Hot applied enamel $\frac{1}{16}$ inch thick to $\frac{3}{32}$ inch thick, wrapper of asbestos pipe line felt or glassfiber wrapper; hot applied enamel $\frac{1}{16}$ inch thick, wrapper of asbestos pipe line felt or glassfiber wrapper; Kraft paper.
Specification No. 4	Primer—Hot applied enamel $\frac{1}{16}$ inch to $\frac{3}{32}$ inch thick, wrapper of asbestos pipe line felt or glassfiber wrapper; hot applied enamel $\frac{1}{16}$ inch thick, wrapper of asbestos pipe line felt or glassfiber wrapper; hot applied enamel $\frac{1}{16}$ inch thick; Kraft paper.



Figure 1—Enamel lined pipe.

In Table 2 some suggested combinations are given for yard coated and wrapped pipe. Specification No. 1 is satisfactory for most soil conditions. The second will provide longer life and is recommended where soil stress conditions and abrasion are more severe. Examples No. 3 and No. 4 are for the heaviest clay soils subject to frequent reversals of wet and dry conditions, or for pipe buried in cinders, or other sharp mechanically destructive fill.

Steel Water Pipe Linings

Steel water pipe also may be treated internally with coal tar enamels to protect the pipe from corrosion and tuberculation, which otherwise will reduce the capacity of the pipe line tremendously. The molten lining material is introduced by a weir or by a trough which is inverted to pour the hot enamel length-wise along the revolving pipe. The centrifugal force developed by the spinning pipe together with the proper viscosity obtained by the pre-selected application temperature of the lining material, causes the latter to flow evenly and adhere tenaciously to the previously primed surface. Figure 1 shows the extremely smooth interior surface of a spun lining. The enamel is usually applied in yards where it is customary to whitewash the entire outside surface of the coated pipe and the ends of the interior lining. This is done to reflect sunlight and thus keep the coating from getting too hot when later exposed along the right-of-way before burial. In the field, the uncoated portions where the pipe sections are joined together are protected with the same material used in the yard coating.

Besides the permanent protection afforded against tuberculation and corrosion, another important advantage of the spun enamel lining is its sustained high flow coefficient.^{5,6}

Highly plasticized enamels meeting the requirements of the American Water Works Association, as given in Table 4, are usually specified as lining for steel water pipe.

The particular type of enamel to be used for a specific installation depends to a great extent upon the type of service expected and upon conditions which vary in different parts of the country and

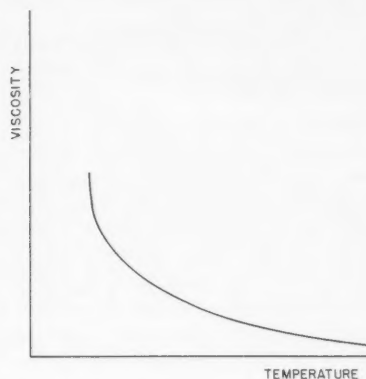


Figure 2—Viscosity decrease with temperature.

between different industries. Proper selection should be made by competently qualified engineers. If any questions arise as to the suitability of the proposed coating, it is advised that the manufacturers of the coating be consulted.

Hot Applied Coatings Specifications

In Tables 3 and 4 are given the commonly specified physical characteristics of different kinds of widely used coal tar enamels available in this country. They include unplasticized and plasticized types (including partially plasticized variations) of coal tar enamels. They usually are specified for underground or submerged structures. The appropriate primer for each enamel should be used in each case as recommended by the manufacturer.

In connection with cathodic protection for underground or underwater installations, current specifications usually call for maintaining an applied potential of approximately 800 millivolts negative to copper sulfate half-cell. Such potentials can be obtained at low current consumption on enameled pipe, and cathodic protection is now being widely recommended for coated pipe lines and other structures, buried or immersed.

The above somewhat overlapping specifications have been condensed for purposes of simplification and practicality by NACE Unit Committee T-2G to provide coal tar enamel specification recommendations for the pipe line industry.⁷

Specification Testing

Softening Point Test

This is an empirical test and has no significance in itself other than to indicate the probable softening range of the material under test. For some bituminous materials it has been claimed that the softening point temperature is that at which the viscosity of the material is approximately 1.2×10^4 poises, equivalent to about 1×10^6 centistokes for coal tar enamels. It should be emphasized that this is an extremely rough approximation, limited by uncertainty about the temperature-viscosity susceptibility of the material and

about its rheological properties in the neighborhood of the softening point.

In Figure 2 is given a graphical representation of the conventional change in viscosity with temperature for most fluids.

Many attempts have been made to write equations to cover changes in viscosity with temperature, or as it is commonly called, Temperature Susceptibility. Over relatively short temperature ranges with viscosities possibly up to as high as 10^6 centistokes, it has been established that a fairly linear relation exists between log log absolute viscosity and log absolute temperature for many thermoplastic bituminous products. Charts provided with different appropriate viscosity and temperature ranges based on this relationship can be obtained from the American Society for Testing Materials.

In Figure 3, typical representative curves are shown to illustrate this point. Curve (A) is pictured as having a slope of about 1.2. Coal tars in general may have temperature susceptibilities close to this value or somewhat higher. Curve (B) represents a material having a susceptibility of 1.0. Most asphalts are reported to have values of 1.0 or lower, on this scale.

If two materials having about the same softening point (represented by X) are heated to application fluidity (represented by Y), it is obvious that the lower the susceptibility the higher must be the temperature necessary to reduce the viscosity to a practical application level to provide proper adhesion and required thickness of coating. Conversely it will take a material like (B) longer to congeal to a solid or semi-solid state after application at suitable fluidity than will be the case for a type (A) material.

Penetration Tests

Needle penetration requirements at one or two temperatures (usually 77 F and 115 F) are used to determine the hardness or softness of the material. If the material is too hard, the coating may be too brittle for necessary handling at low temperatures after application, whereas if the penetration is too high the coating may be damaged by scuffing, smearing, rubbing, or other mechanical contact causing exposure of bare metal.

Suggested relations between penetration and viscosity appear to be untrustworthy even for materials exhibiting simple flow relations (as described below).

TABLE 3—Unplasticized Enamels

TEST	ENAMEL NO.						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Softening Point, Degrees F, (R+B) (ASTM D-36).....	165-175	180-190	185-195	185-200	190-200	190-200	195-205
Penetration (ASTM D-5)							
@ 77 F, 110 gms, 5 sec.....	0-4	0-2	0-2	0-3	0-1	0-2	0-2
@ 115 F, 50 gms, 5 sec.....	17-32	2-8	1-8	0-10	1-6	0-8	3-8
Ash, %, (Filler) (ASTM D-271).....	30-35	20-25	15-25	20-30	20-25	20-25	34-39
Specific Gravity @ 25 C (ASTM D-71)...	1.51-1.61	1.40-1.50	1.40-1.50	1.40-1.60	1.40-1.50	1.45-1.55	1.55-1.65
High Temperature Sag (AWWA C-204)							
5 hours, 100 F, max.....	1/16"						
5 hours, 120 F, max.....		1/16"		1/16"	1/16"	1/32"	1/16"
5 hours, 140 F, max.....							
24 hours, 160 F, max.....							
Low Temperature Crack (AWWA C-204)							
No Cracks, 45 F, after.....							
No Cracks, 30 F, after.....							
No Cracks, 20 F, after.....	6 hours	6 hours	5 hours	6 hours	6 hours	5 hours	6 hours
No Cracks, 10 F, after.....							
No Cracks, -10 F, after.....							
No Cracks, -20 F, after.....							

TABLE 4—Plasticized Enamels

TEST	ENAMEL NO.							
	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15) ¹
Softening Point, Degrees F, (R+B) (ASTM D-36).....	185-195	190-200	190-205	195-205	220-235	220 min.	220 min.	220 min.
Penetration (ASTM D-5)								
@ 77 F, 110 gms, 5 sec.....	2-7	2-6	2-7	2-5	4-9	5-10	7-11	10-20
@ 115 F, 50 gms, 5 sec.....	10-30	10-20	10-20	10-25	12-25	12-25	14-28	15-55
Ash, %, (Filler) (ASTM D-271).....	20-30	20-25	18-22	25-35	20-25	25-35	20-25	25-35
Specific Gravity @ 25 C (ASTM D-71).....	1.40-1.60	1.40-1.50	1.37-1.47	1.45-1.60	1.35-1.45	1.45-1.60	1.40-1.50	1.40-1.60
High Temperature Sag (AWWA C-204)								
5 hours, 120 F, max.....	1/16"	1/32"	1/16"	1/16"	1/16"	1/16"	1/32"	1/16"
5 hours, 140 F, max.....								
24 hours, 160 F, max.....								
Low Temperature Crack (AWWA C-204)								
No Cracks, 10 F, after.....								
No Cracks, 0 F, after.....	6 hours	5 hours	6 hours	5 hours	6 hours	6 hours	5 hours	6 hours
No Cracks, -10 F, after.....								
No Cracks, -20 F, after.....								

¹ American Water Works Association Type.

In Figure 4 are given experimental results obtained⁸ to test a suggested relation between penetration and viscosity for bituminous materials. The curved line shows the departure from the predicted straight line formula relationship. The greatest departure covers the penetration range usually found in enamel specifications.

This means that attempted empirical correlations between penetration values and flow properties may be completely misleading. Essentially penetration is a measure of hardness or softness only—it provides information for the technologist on the probability or improbability of embrittlement or puncturing of the coating, both of which are in turn dependent upon prevailing low or high temperatures, and are further modified in service by joint use of coating reinforcements and wrappers.

In Figure 5 two types of flow frequently encountered are presented.

Newton defined "viscosity" as the constant ratio of shearing force to rate of shear. This means that no matter what force is used to measure the viscosity, the ratio of shearing force applied to rate of shear observed is always constant, and therefore, a graph of the two components must be linear and go

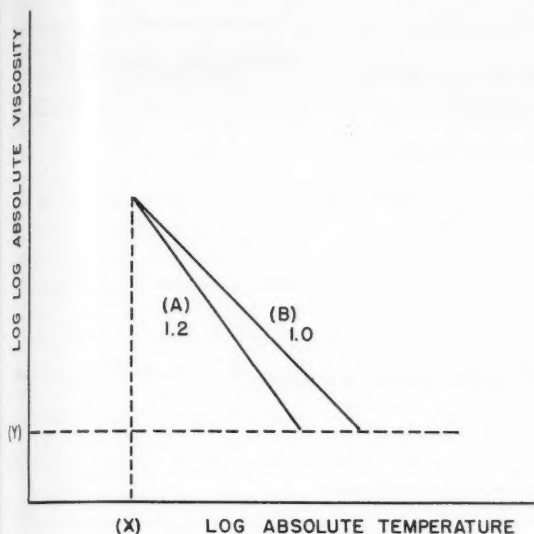


Figure 3—Viscosity temperature susceptibility.

through the origin. A material such as this (Figure 5, Curve C), commonly called a simple or Newtonian fluid, must start to flow no matter how little force is exerted upon it. Curve (C-1) represents another Newtonian fluid of higher viscosity than Curve (C), but also exhibiting no yield value.

In contrast are fluids which will not exhibit flow until a certain minimum stress is exceeded. This general type is represented by Curve (D). Here the curve has a definite linearity, until it approaches the shear axis. Whether the curve would intercept this axis if the extrapolated portion could be experimentally determined, or whether it might actually approach the origin tangentially to the axis of shear is not important. The practical point is that such a material will not exhibit significant flow until the yield value represented by (E) is exceeded. (D-1) represents a material of higher consistency and higher yield value, (E-1) than that denoted by Curve (D).

In Figure 6 are given data illustrating the simple flow characteristics of "hard" apparently solid, flat roof pitches. Within experimental error it was established⁸ without question that these pitches all have constant viscosities and zero yield values. These products, therefore, are "Newtonian" in flow characteristics. This means that they behave like liquids and tend to exhibit cold flow if placed under the slightest stresses; they are, therefore, excellent materials for builtup pitch and felt flat roofs because of this property which promotes during every warm spell complete resealing of any cracks which may have occurred in previous periods of freezing weather. They would, of course, be most unsuitable for application to other than flat surfaces.

On the other hand in Figure 7 are given rheological diagrams for a "soft" pasty experimental material. When first poured and measured at different shear-

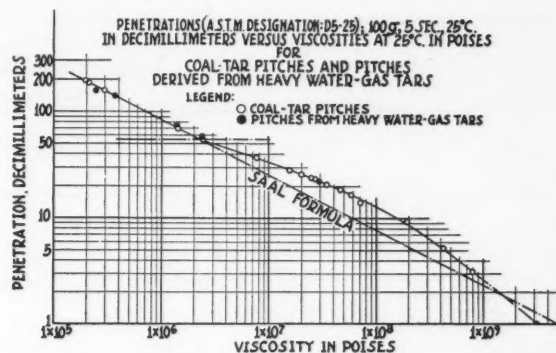


Figure 4—Relation between penetration and viscosity for bituminous materials.

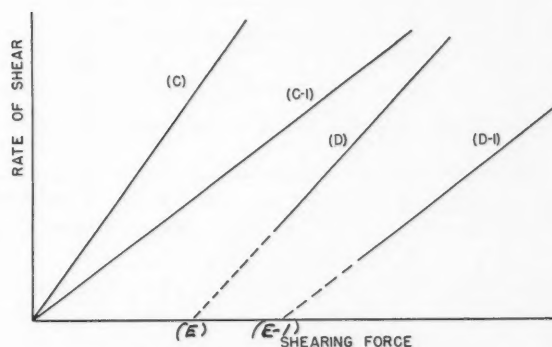


Figure 5—Newtonian and non-Newtonian flow.

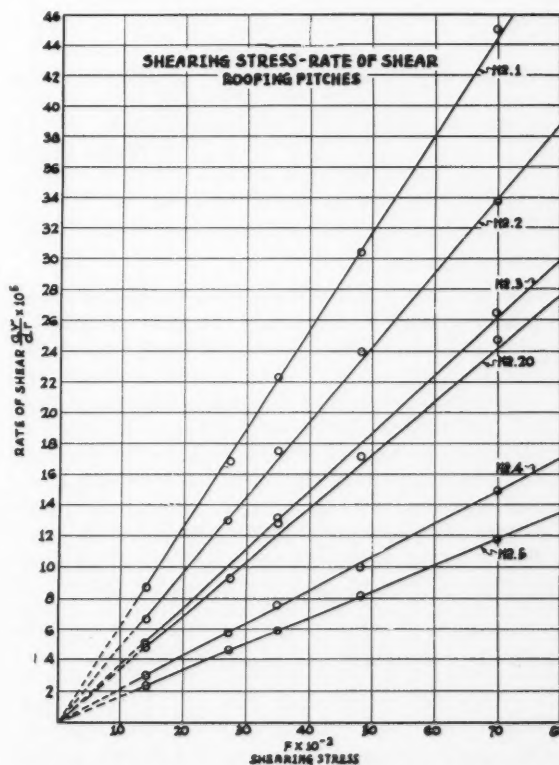


Figure 6—Shearing stress-rate of shear roofing pitches.

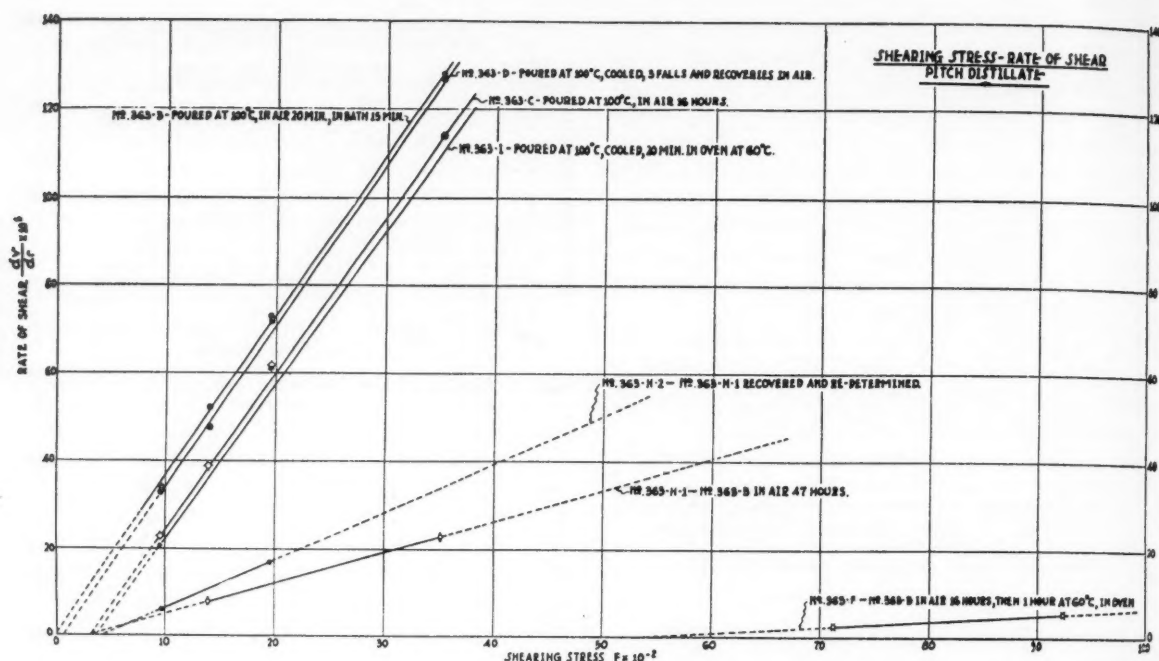


Figure 7—Shearing stress-rate of shear pitch distillate.

ing stresses, the material appeared to be Newtonian in character and to have no yield value. However, upon standing, duplicate samples of this soft composition allowed to remain undisturbed for varying periods until the time of measurement, developed higher and higher consistencies and definite yield values, despite the extreme softness of the composition.

Addition of the proper amount of suitable inert filler and control of the softening point of the resultant filled product imparts flow resistance at service temperatures to the enamel coating. Increased resistance to flow is furthered materially by use of wrappers and/or reinforcements.

Ash Determination

To influence the flow properties in the desired direction, as indicated above, certain amounts of different finely divided inert fillers are incorporated in these hot applied coal tar coatings. The nature, amount, and particle size vary somewhat depending upon individual preferences, but usually they are selected to conform to the enamel properties given in Tables 3 and 4. The filler obviously has relatively little effect on the consistency of the coating in the fluid condition near the application temperature, but it has a marked effect in contributing to non-cold flow characteristics of the coating under service conditions at lower temperatures. The ash determination is done by burning a sample of the coating in a weighed crucible and weighing the residue obtained.

Sag Test

Coated panels may be suspended for definite periods of time, after scribing, in ovens at preselected elevated

test temperatures. Movement of the scribe line indicates undesirable sagging of the coating. If the softening point is sufficiently high there is little likelihood of coal tar coatings failing to satisfy this requirement.

Brittleness Test

After completion of the sag test the same panel is subjected to preselected low temperatures for specified periods of time, undisturbed, and then inspected for cracking. Generally speaking the coating will show no cracks at the test temperature if the penetration of the material is sufficiently high. These simple specification requirements are a practical guarantee that the coating if known to be essentially of coal tar origin, will be similar to products previously used and previously found to exhibit the required physical properties and to be chemically inert in the corrosion environment anticipated.

The ideal material would be one of moderately high softening point (non-flow), of high temperature susceptibility in the fluid state (ease of application and rapid congealing), of appropriate filler content (non-flow in service), of non-Newtonian flow characteristics and high yield values under service conditions (rheological stability, resistance to stresses), and of proper penetration values for conditions anticipated (non-brittle, non-puncture).

It should be kept in mind that none of the above empirical tests guarantee definite quality performance, but all these requirements taken together and satisfied simultaneously ensure satisfactory performance in service provided that the material is known to be of a type that unquestionably exhibits initial and enduring low water absorption and high electrical resistivity, and has a past record of proven good service behavior.

Performance Test—Fundamental Properties

One of the most important properties of a bituminous (or any other) coating, is its resistance to absorption of, or permeability by, liquid water.

The first step in establishing the resistance offered by protective coatings to absorption of water is to coat a steel or aluminum plate of convenient dimensions with the system or material under investigation, weighing the plate before and after coating to obtain the coating weight by difference. (If the system is cold applied, the sample must be allowed to come to constant weight in air, or in an oven at moderate drying temperatures, before it is subjected to test.) The test sample is then immersed in gently flowing water in a suitable tank, removed periodically, and weighed after wiping the coated surface dry. From the changes in weight and the dimensions of the sample, the water absorbed per square foot of coated surface can readily be calculated. If the sample exhibits a decrease, rather than an increase in weight, the coating is losing leachable material by solution in the water, indicating dubious protective properties.

Occasionally water absorption values have been determined by immersing weighed cast cubes of the material in question in water and weighing periodically. Other investigators have daubed the molten coating on glass slides and then followed a similar immersion and periodically weighing procedure.

Whatever the method used, the results obtained from water absorption test studies lend themselves readily to graphical presentation. The graphs in Figure 8 were made in this way by Hayes¹⁰ and compare coal tar enamels with asphalt enamels in their resistance to water absorption. These curves represent one of the early authoritative reports on this subject and show that filled and unfilled asphalt enamels have much higher water absorption characteristics than have coal tar enamels. The flat curve for coal tar enamel portrays all the characteristics of a truly permanent waterproof material. The rates at which the asphalt curves are rising indicate eventual failure.

Data substantiating the curves appearing in the Journal of the American Water Works Association have been provided by personnel of the Barrett Division, Allied Chemical & Dye Corporation, for use in educational programs. They ran water absorption tests on coal tar enamels, asphalt enamels, and mixed enamels made by blending asphalts, or tars and asphalts. Instead of stopping at 100 days, they extended the test period to a full 500 days. In Figure 9 which shows the outcome of this work, the superiority of the coal tar products is unmistakable.

Some of the earlier investigators reported the water absorption results in terms of weight percent. Weight

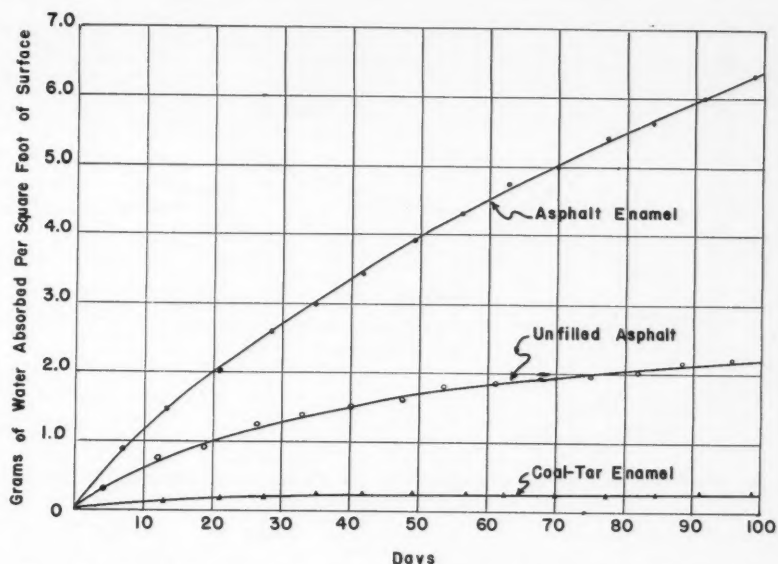


Figure 8—Water absorption rate for asphalt enamel, unfilled asphalt and coal tar enamel.

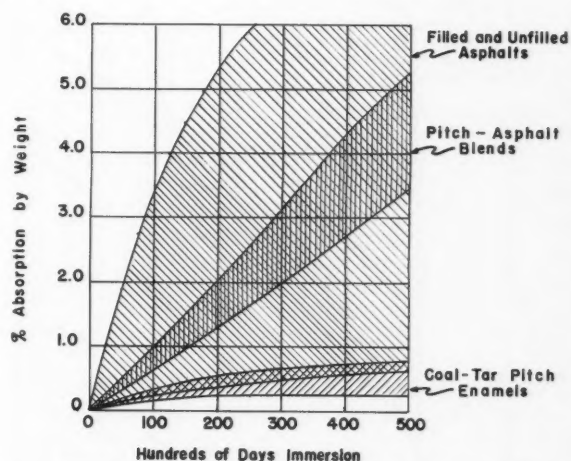


Figure 9—Water absorption (percent by weight) of bituminous coatings.

per unit area is preferable because in these units all results are on a common basis and differences in thicknesses, and therefore, in all weights of coatings do not confuse the results.

For example, one square foot of surface coated with one quarter inch thick enamel might absorb in a given time the same amount of water as an identical area having a one inch thick coating. The results would be equivalent in grams per square foot, but would be quite different if expressed in weight percent, because of the much higher weight of the thicker coating.

The more absorptive coatings are customarily applied thicker. Reporting water absorption by weight percent would not show differences between these and the less absorptive coal tar coatings, whereas reporting absorption in weight per unit area (grams per square foot) does bring out this difference.

In the Koppers Company laboratories samples of various competitive materials are still under test after having

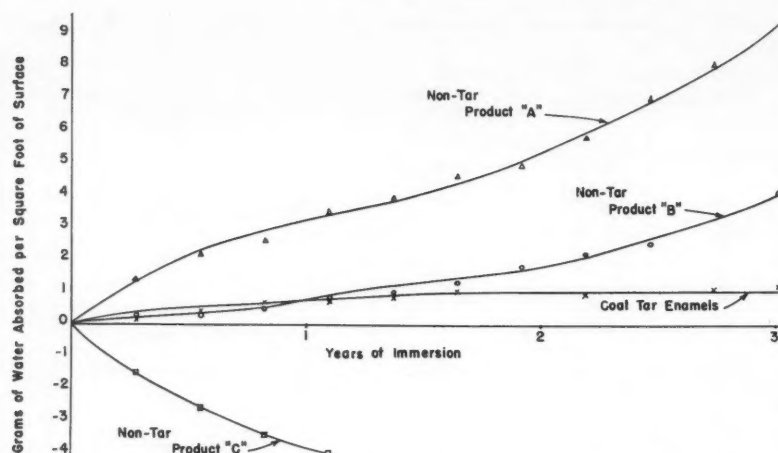


Figure 10—Water absorption of commercial pipe line enamels. Note comparison of coal tar enamels with non-tar enamels.

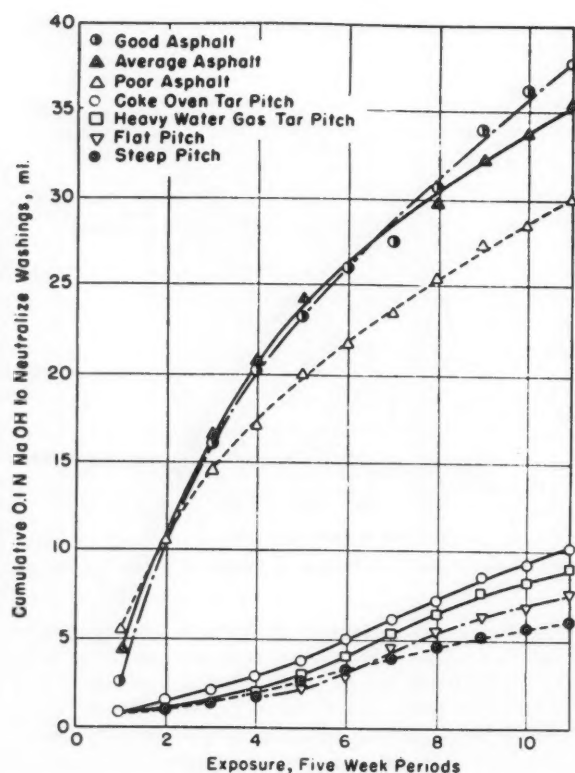


Figure 11—Neutralization of leaching liquors. 0.1 N NaOH required to neutralize washings from bituminous materials exposed to ultraviolet light.

experienced over three years immersion exposure. All the coal tar enamels, irrespective of type, exhibit low water absorption characteristics. Asphalt enamels including so-called improved variations continue to show the same high water absorptions that characterize the asphalts in Figures 8 and 9, although in the case of some of the "improved" variations, a somewhat longer period of test is required before the absorption curves start upward. After a delayed start the same pattern of rapid

rise in water absorption is found. One of the competitive coating materials of the petroleum wax type was found to lose weight rapidly, indicating considerable solubility in water.

Graphical presentation of the experimental data amply supporting the above statements will be found in Figure 10. The products represented by the curves "A" and "B" are the improved type; "C" is a wax coating.

It has been observed that non-tar enamels appear dull and rough on extended immersion, indicating surface changes, while the coal tar enamels remain shiny and smooth.

It has been claimed that not water "absorption," but water "transmission" is the important requisite for a good coating. It is hard to visualize a process of progressive absorption that does not involve deeper and deeper penetration of water into the coating with time, resulting in eventual loss of protective properties.

Beckman, Badger, Gullekson, and Stevenson¹¹ determined the diffusion constants for certain bituminous materials and found them to be very low. However, their data show lower values for coal tar pitches and filled coal tar pitches than for the other bituminous materials.

Anderson and Wright¹² similarly found very low water permeability for various bituminous coatings, plasticized pitch (containing 35 percent inorganic filler) being much lower than the asphalts and coal tar pitch.

These authors stated that soaking tests may be subject to criticism because by this test coal tar pitches generally show a smaller gain in weight than petroleum asphalts and thus inferentially a lower water absorption. They claimed also that such a test may be in error because coal tar pitches may lose soluble constituents to the water phase, and therefore show a net gain in weight less than the true water absorption. Quantitative data for the leaching of bituminous materials by water do not support this speculation.

Reference may be made to the work of Strieter and Snoke.¹³ As a result of accelerated aging tests on asphaltic and other materials, these investigators pointed out that water soluble acidic material was produced and subsequently dissolved by the alternate action of ultraviolet light and water. At the 1949 Annual Meeting of the American Society for Testing Materials, a symposium was held on the Accelerated Durability Testing of Bituminous Materials. The type of accelerated investigation described by Strieter and Snoke was used to examine the effect of ultraviolet light and water upon a group of representative pitches and a report was given at this symposium.¹⁴ The materials tested were three asphalts reported by a user to exhibit good, average, and poor weathering qualities, several standard roofing pitches (both flat and steep) and some high melting pitches with and without incorporated filler. Panels coated with these materials were alternately submitted to ultraviolet light,

heat, and air exposure in a weatherometer 9½ hours a day and then immersed for four hours daily in distilled water. The heat is incidental to the weatherometer operations; the temperature was approximately 150 to 165 F. After each five-week period, the immersion water was titrated to neutrality with N/10 sodium hydroxide, the solution evaporated to dryness, and the water soluble material leached from the individual samples was determined by weighing.

In Figure 11 the data obtained when the individual leaching liquors were neutralized are given; in Figure 12 the solids obtained over this 55-week leaching test are presented graphically.

There is no reason to believe that the material leached out in water absorption tests would be greater than the amounts determined as described above. Therefore, the hypothesis that reported low water absorption characteristics of coal tar enamels are due to counter-balancing leaching appears to be untenable. Differences between these products become more noticeable when there is a possibility of exposure to ultraviolet light, as well as to water.

Electrical Resistivity

Laboratory measurements give values of the order of 10^{12} to 10^{15} ohms per cubic centimeter for coal tar enamels. Little change in these values has been found during immersion in water for over one year for samples of different types and sources. Some variation has been observed in the same time for samples of different asphalt enamels. Electrical resistivities will be determined periodically for all these immersed samples in continuing tests.

Oil Spillage Resistivity

Complete immersion in petroleum products has little effect upon the unplasticized coal tar enamels, even after long periods of time. The plasticized enamels are somewhat less resistant to prolonged contact with petroleum products, but are superior in this respect to other types of bituminous coatings.

Soil Stress Resistance

Usually this type of investigation is conducted in the laboratory on pipe samples coated with enamel and wrapper and/or reinforcements. A mud made of a known "hot" soil and water is thickly applied to the exterior surface and allowed to dry slowly. This dry cake is then removed and the cycle repeated, observations being made each time on the extent of damage done to the wrapping and coating by the stresses set up during the drying process. Several cycles are usually necessary before any effect on the coating can be detected.

Summary

Specification tests and fundamental properties of coal tar enamels have been described.

Condensed specifications for recommended coal tar enamels of proven excellent service performance

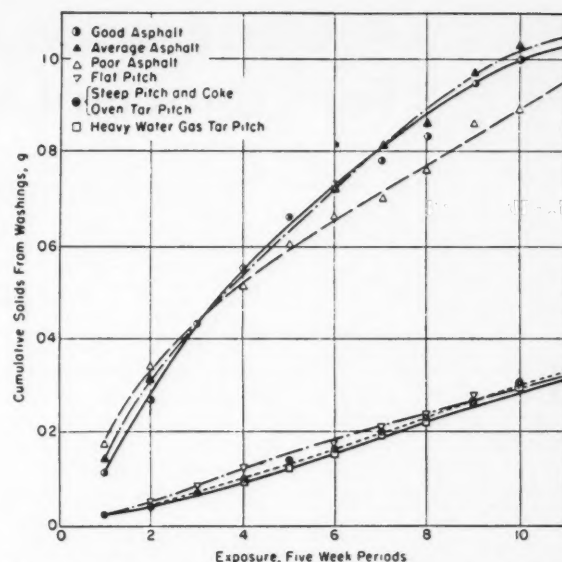


Figure 12—Solids contained in neutralized washings from bituminous materials exposed to ultraviolet light.

probably will be tabulated soon by the Technical Practices Committee, based on work originating in Unit Committee T-2G.

Typical recommendations of protective coating combinations for different environments based on service experience will be presented at the end of Part 2 of this paper.

References

1. T. F. P. Kelly. Fifth Soil-Corrosion Conference, National Bureau of Standards, 1943.
2. J. C. Stirling. *Corrosion*, **1**, 17-30, (1945) Mar.
3. O. C. Mudd. *Corrosion*, **1**, 192-218, (1945) Dec.; **2**, 25-55, (1946) Mar.
4. Report: Corrosion Committee, DMC-53-3, "Survey of Corrosion Mitigation Practices on Underground Gas Pipes," Amer. Gas Assoc., Operation Section, Apr., 1953.
5. Carpenter and Roads. *Journal New England Water Works Assoc.*, **56**, 8-13, (1942, Mar).
6. G. E. Burnett. *Journal American Water Works Assoc.*, **42**, Pt. 2, 741-748, (1950) Aug.
7. NACE Technical Committee T-2G Report. *Corrosion*, **12**, 75-76, (1956) Jan.
8. Fair and Volkmann. *Ind. Eng. Chem., Anal. Ed.*, **15**, 240-242, (1943) Apr.
9. Fair and Volkmann. *Ind. Eng. Chem., Anal. Ed.*, **15**, 235-239, (1943) Apr.
10. H. Hayes. *Journal American Water Works Assoc.*, **32**, 1705-1722, (1940) Oct.
11. Beckman, Badger, Gullekson and Stevenson. *Ind. Eng. Chem.*, **33**, 984-990, (1941) Aug.
12. Anderson and Wright. *Ind. Eng. Chem.*, **33**, 991-995, (1941) Aug.
13. Strieter and Snoke. *Journal Research*, National Bureau of Standards, **16**, 481-485, (1936) May.
14. Fair, Beck and McKee. ASTM, Special Technical Publication No. 94.

End of Part I

Part 2 will be published in the December, 1956 issue.

A Classification and Filing System For Corrosion Literature*

By W. L. MATHAY and R. B. HOXENG

Introduction

THE TREMENDOUS growth in public recognition of the importance of corrosion in modern technology has been paralleled or even surpassed by the increased amount of technical literature published on the subject of corrosion and corrosion control. Over the last two decades the number of technical articles per year in this field has increased many-fold, and the trade literature related to corrosion prevention and corrosion-resistant materials has become very voluminous. Although it is true that the published literature is a great boon to those working in the field, it is also true that the quantity of the literature has now reached a point where it is impossible for any corrosion engineer to be conversant with all the publications. Therefore it has become necessary to develop elaborate methods of abstracting this literature and filing and cross-indexing it in such a way as to make it readily available when needed.

The National Association of Corrosion Engineers recognized the need for an abstract service designed specifically for the field of corrosion. Under NACE sponsorship, a group of experts in the field worked out an elaborate subject index, the NACE Abstract Filing Index, with random numbers. In addition to including coded abstracts of important corrosion literature in their monthly journal, *Corrosion*, the NACE undertook a two-fold approach toward providing a very comprehensive abstract service of corrosion literature. First they started publishing biennial volumes of coded abstracts of corrosion literature, called Bibliographic Surveys. To date four volumes have been published including about 14,000 abstracts of corrosion literature covering the period primarily from 1945 to 1951 but also including some abstracts of previous literature. A fifth volume for the period of 1952 and 1953 also has been published (publication of such volumes must of necessity be several years behind current literature to permit complete coverage.)

To supplement the Bibliographic Surveys, the NACE initiated in 1951 an Abstract Punch Card Service in which subscribers are provided with almost 2,000 coded corrosion abstracts per year. These are printed on punch cards which are pre-punched for subject matter by the NACE to facilitate their use by the subscriber. The cards are marked in such a manner that the subscriber, if he so desires, may punch the cards to indicate the author, journal reference, and original reference date. Extra holes also



W. L. MATHAY—Technologist, Applied Research Laboratory, United States Steel Corporation, Monroeville, Pa. He received a BS degree in chemistry from Thiel College in 1947 and completed requirements for an MS degree in chemistry at Carnegie Institute of Technology. He had several years of experience in water treatment before joining the U. S. Steel Corporation in 1954. As Section Leader of the Chemical and Process Corrosion group he is now engaged in the mitigation of corrosion problems, particularly in the coal chemical field. Mr. Mathay is a member of NACE.

R. B. HOXENG—Assistant to the Director, Applied Research Laboratory, U. S. Steel Corporation, Monroeville, Pa. Prior to joining U. S. Steel he was associated with Case Institute of Technology. He did graduate work in physical chemistry at Iowa State College, the University of Pittsburgh and Case Institute (where he received a PhD in 1949). Dr. Hoxeng worked for the Manhattan Project and has done corrosion research at Iowa State College, the University of Chicago and for the Aluminum Company of America.



Abstract

A method has been developed for the classification and filing of abstract punch cards and literature on the subject of corrosion. The method involves the use of an adaptation of the subject filing index devised by the National Association of Corrosion Engineers for use with NACE corrosion-abstract punch cards. The NACE index divides corrosion literature into eight main topics, each of which is further subdivided, and designates random-number codes to be used in sorting the cards for second-order subdivisions. In the newly-developed classification and filing index, the second-order subdivisions of the NACE index have been generalized to permit the filing of cards according to main fields of interest, such as corrosive environments, preventive measures, and materials of construction. This method of filing, which provides for expansion of existing files and which considerably reduces the time and effort required in sorting for information, may also be applied to other corrosion literature. 1.7.1

are provided on the cards to permit an expansion of the NACE indexing system. By means of this service, abstracts of corrosion literature are provided to subscribers a short time after the initial publication.

Through these two services the NACE is providing the most complete abstracting coverage of corrosion literature that is available today. Although it may have been expected that the Bibliographic Surveys

* Submitted for publication August 13, 1956.

would be more useful than the punch cards for reviewing corrosion literature, it has been found that there are many advantages to be gained by the use of the cards even for those previous years covered by both the cards and the Bibliographic Surveys.

The NACE corrosion-abstract punch cards may be random filed, or filed in any of several ways according to the needs of the user. The cards may be hand sorted or machine sorted, again depending on the wishes of the subscriber. U. S. Steel's efforts have been directed toward simplifying the handling and sorting of the cards and yet providing an efficient method of procuring information. Therefore, a procedure for classifying and filing corrosion literature

was devised based on a modification of the NACE subject filing index and designed to be particularly valuable for a company concerned with the selection of constructional materials for its own and customers' plants. The new system not only expands the usefulness of the NACE corrosion-abstract punch-card system but also permits the handling of a much larger number of cards.

Because the classification and filing system is based on the NACE filing index, and utilizes the NACE corrosion-abstract punch cards, a brief description of the NACE subject filing index will be of value in understanding the classification and filing system. A bibliography of articles pertaining to the NACE abstract filing system is given at the end of this paper.

NACE Abstract Subject Filing Index

The very comprehensive NACE abstract subject filing index which was developed for use with the punch cards divides corrosion literature into the following eight Main Topics:

1. General
2. Testing
3. Characteristic Corrosion Phenomena
4. Corrosive Environments
5. Preventive Measures
6. Materials of Construction
7. Equipment
8. Industries

Each of these Main Topics is further divided into different first-order and second-order subdivisions which cover specific subjects related to the Main Topics. The complete NACE abstract filing index is published annually in December issues of *Corrosion* journal.

One of the difficulties in filing abstracts on corrosion literature is that most technical articles pertain to several phases of the subject. To avoid the necessity of duplicating each abstract for multiple filing, it was decided to use multiple coding of abstract punch cards so that the cards could be found by

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
<p>②3.2., 6.2.5</p> <p>Electrolytic Etch Cuts Corrosion Test Time. J. D. Roach and H. H. Hollenbeck. Iron Age, 173, No. 25, 100-103 (1954) June 24.</p> <p>Corrosion-test time for some stainless steels is sharply cut with a new electrolytic oxalic acid etch test, which indicates susceptibility to intergranular corrosion. Several AISI types of stainless steel (fully annealed and sensitized) were tested to compare the effects of oxalic and nitric acid; the oxalic acid method is effective in Types 302, 304, and 316. After etching, specimens were classified according to structure (ditch, step, and dual type noticed). The test can also be used to show whether stabilized grades are completely stabilized. Stabilized stainless cannot be tested for corrosion by the oxalic method because of sigma formation.</p>																											

Figure 1—NACE corrosion-abstract punch card.

sorting for any of several subjects. Because the system known as random-number coding permits maximum flexibility, random numbers are assigned by the NACE to each of the second-order subdivisions, as in Table 1, or to each of the first-order subdivisions where there are no second-order subdivisions. The random-number codes consist of sets of four numbers, and not more than five sets may be used on a single card.

The type of punch card used by the NACE is a 5- by 8-inch McBee Keysort card with a double row of holes around the perimeter. The subject classification numbers, 2.3.2, and 6.2.5, assigned by NACE to the card illustrated in Figure 1 represent Main Topics 2 and 6 and their appropriate first- and second-order subdivisions. These numbers are placed in the upper left corner of the face of the card in order of importance from left to right. The holes in the outer row along the top of the card are numbered from 1 through 28 and are notched by the NACE according to the random-number codes which in the example designate the second-order subdivisions, 2 and 5, under first-order subdivisions 3 and 2 of the respective Main Topics 2 and 6.

The inner row of holes along the bottom of the NACE corrosion-abstract punch card is for the subscribers' use in designating the journal reference and the original reference date according to the NACE date and journal reference codes. Both the outer and inner row of holes along the left-hand side of the card may be utilized to identify the author or authors of the reference according to the NACE author code. A complete description of the NACE abstract punch card and the NACE coding systems may be found in Dr. I. M. Parker's article, "The Literature on Corrosion," *Corrosion*, 7, No. 12, pages 450 to 453, December 1951.

Classification and Filing System for Corrosion Literature

In the classification and filing system all Main Topics are used, but Main Topics 4 (Corrosive En-

vironments), 5 (Preventive Measures), and 6 (Materials of Construction) are considered to be of principal interest. Therefore, for filing purposes the punch cards are grouped in the following manner:

1. Any card having one of the Main Topic numbers 4, 5, or 6 in the subject classification numbers at the top of the card is filed with that main group. If a card has more than one of these Main Topic numbers it is arbitrarily filed with the lower-numbered group.
2. All other cards are filed according to the Main Topic number (1, 2, 3, 7 or 8) of the most important subject classification number on the card (not necessarily the lowest numbered Main Topic).
3. All cards which have been placed with Main Groups 4, 5, and 6 as a result of Step 1 are next further subdivided according to the first-order subdivision number of the selected Main Topic number. The cards placed in the other main groups are not subdivided according to the first-order subdivision until the groups become too large for convenient handling.
4. All groups of cards resulting from Step 3 that have a large number of cards, say over 200 cards, are given a final breakdown according to the Main Topic number of the second most important subject classification number listed on the card (not according to the second-order subdivision). Cards which have only one subject classification number are placed in the general category for the final breakdown—Main Topic 1.

For purposes of filing the cards initially and replacing them after a search has been made, each card should be marked on the basis of the subject classification numbers at the top of the cards. The marking procedure consists of underlining the Main Topic

number (Steps 1 and 2) and the first-order subdivision number (Step 3) of the selected subject classification number, and placing a circle around the Main Topic number of the second most important subject classification number (Step 4). The amount of time required to mark the 175 cards received monthly from the NACE and to place them in the proper file locations is about 45 minutes.

From the above discussion it should be apparent that the chief difference in the two filing systems is in the second-order subdivisions. The NACE Subject Filing Index has very specific second-order subdivisions which are the basis of the random number code, whereas in the classification and filing index the second-order subdivisions are in reality the eight Main Topics of the NACE subject filing index. This difference is illustrated in Table 2 which shows the breakdown of section 4.3 in both systems. The classification and filing index, abbreviated somewhat to avoid repetition, is shown in Table 3. It should be noted that because a card which refers to more than one of the Main Topic numbers 4, 5, and 6 is placed with the lower-numbered group, there can be no second-order subdivisions in Table 1 that are numbered (4) under Main Topic 5, or (4) or (5) under Main Topic 6.

The classification and filing index supplements the NACE subject filing index but does not replace it. It is still necessary to refer to the NACE subject filing index to obtain the random-number codes. Furthermore, since the NACE second-order subdivisions determine the random-number code, and since the cards are pre-punched for this code, full use can be made of the NACE subject filing index while

TABLE 1—Portion of NACE Abstract Subject Filing Index
(With Random Numbers)

4. Corrosive Environment	
1. -----	
2. -----	
3. Chemicals, Inorganic	
1. General	3-9-23-25
2. Acids, Acid Anhydrides, Acid Salts	2-4-7-10
3. Bases, Basic Anhydrides, Basic Salts	11-12-17-23
4. Mixtures	4-12-15-26
5. Nonmetallic Elements	4-15-22-27
6. Salts	15-18-19-24
7. Other	5-15-26-27

TABLE 2—Comparison of Second-Order Subdivisions in NACE and Classification and Filing Indexes

NACE System	Classification and Filing System
4. Corrosive Environments	4. Corrosive Environments
1. -----	1. -----
2. -----	2. -----
3. Chemicals, Inorganic	3. Chemicals, Inorganic
1. General	(1) General
2. Acids, Acid Anhydrides, Acid Salts	(2) Testing
3. Bases, Basic Anhydrides, Basic Salts	(3) Characteristic Corrosive Phenomena
4. Mixture	(4) Corrosive Environments (Combinations)
5. Nonmetallic Elements	(5) Preventive Measures
6. Salts	(6) Materials of Construction
7. Other	(7) Equipment
	(8) Industries

TABLE 3—Classification and Filing Index for Corrosion Literature

1. General
2. Testing
3. Characteristic Corrosion Phenomena
4. Corrosive Environments
1. General
2. Atmospheric
3. Chemicals, Inorganic
NACE Main Topics (1) through (8)
4. Chemicals, Organic
NACE Main Topics (1) through (8)
5. Soil
6. Water and Steam
NACE Main Topics (1) through (8)
7. Molten Metals
8. Other
5. Preventive Measures
1. General
2. Cathodic Protection
3. Metallic Coatings
NACE Main Topics (1) through (8) excluding (4)
4. Nonmetallic Coatings and Paints
NACE Main Topics (1) through (8) excluding (4)
5. Oil and Grease Coatings
6. Packaging
7. Treatment of Medium
8. Inhibitors and Passivators
9. Surface Treatment
NACE Main Topics (1) through (8) excluding (4)
10. Other
6. Materials of Construction
1. General
2. Ferrous Metals and Alloys
NACE Main Topics (1) through (8) excluding (4) and (5)
3. Non-Ferrous Metals and Alloys—Heavy
NACE Main Topics (1) through (8) excluding (4) and (5)
4. Non-Ferrous Metals and Alloys—Light
NACE Main Topics (1) through (8) excluding (4) and (5)
5. Metals—Multiple or Combined
6. Non-Metallic Materials
7. Duplex Materials
8. Other
7. Equipment
8. Industries

gaining the selectivity afforded by the classification and filing index.

Method of Search Using Classification and Filing System

To search the card file for information, the first step is to consult the NACE subject filing index to decide under which Main Topics and their subdivisions the desired information would fall, and to obtain the necessary random-number codes. The next step is to consult the classification and filing index to determine which group or groups of cards should be sorted. It should be pointed out that after brief usage of the classification and filing index, the searcher becomes quite familiar with it and can very quickly select the desired locations for sorting. The cards are removed from the file and sorted, and those dropped as a result of sorting are scanned to determine which are applicable to the subject of interest. The non-pertinent cards are returned to the files and the pertinent cards are given to the engineer requesting the search.

Illustrations

The following examples will illustrate the mechanics of using the classification and filing system.

Example 1—When it was desired to locate references to the effects of fabrication and heat treatment on the corrosion resistance of steels (low carbon through stainless), examination of the NACE subject filing index showed that the cards could be found under Main Topic 3 (Characteristic Corrosion Phenomena) and revealed the random number assigned to fabrication and heat treatment (9-15-21-26). Examination of the classification and filing index indicated that Main Group 3 and Group 6.2(3) were the most logical for sorting, but that the search should also include Groups 4.2, 4.3(3), 4.4(3), 4.6(3), 5.3(3), 5.4(3), and 5.9(3). The results of this search showing the number of cards handled, the number of cards dropped by sorting, and the number of pertinent dropped cards are shown in Table 4. It can be seen that 135 of the 149 wanted cards were found in Groups 3 and 6.2(3). Furthermore, the 149 pertinent cards were obtained by sorting only 1,470 cards out of a total of about 8,000 cards. The time required for the search was about one hour including the time for tabulation of results.

TABLE 4—Results of Search for Abstract Cards on the Effect of Fabrication and Heat Treatment on the Corrosion Resistance of Steels, Low Carbon Through Stainless (Example 1)

Groups Sorted	Cards Handled	Cards Dropped	Pertinent Cards
Group 3.....	695	97	71
Group 6.2 (3).....	370	93	64
Group 4.2.....	170	9	4
Group 4.3 (3).....	25	1	1
Group 4.4 (3).....	10	1	0
Group 4.6 (3).....	35	0	0
Group 5.3 (3).....	60	16	6
Group 5.4 (3).....	60	2	2
Group 5.9 (3).....	45	9	1
Totals.....	1470	228	149

Example 2—Another illustration is the search made for accelerated corrosion tests for use with steels (low carbon through stainless). The random-numbers for accelerated tests were obtained from the NACE subject filing index. Because Main Topic 2, Testing, was the topic of interest, it was decided from an inspection of the classification and filing index that the most logical groups for sorting were Groups 2 and 6.2(2), and that additional possibilities were Groups 4.2, 4.3(2), 4.4(2), 4.6(2), 5.3(2), and 5.9(2). The results of this search are shown in Table 5. The number of pertinent cards was 60 of which 44 were found in Groups 2 and 6.2(2). In all, 855 cards were handled and the time required for the search was 45 minutes.

Example 3—One final example is that of a search for references to stress-corrosion cracking of stainless steels. This particular search illustrates the maximum utility of the classification and filing system. The random numbers assigned to stress-corrosion cracking (second-order subdivision under Main Topic 3) and to stainless steels (second-order subdivision under Main Topic 6) were first obtained from the NACE subject filing index. In addition, because a section under testing (Main Topic 2) deals with stress-corrosion cracking, it was considered desirable to obtain these random numbers also. The classification and filing index was then consulted, and it was decided a search should be made of cards filed under Groups 2, 3, 6.3(2), and 6.2(3). Subsequently, in order to make the search as complete as possible Groups 4.2, 4.3(2), 4.3(3), 4.3(6), 4.4(2), 4.4(3), 4.4(6), 4.6(2), 4.6(3), 4.6(6), 5.9(2), and 5.9(3) were sorted also. It should be pointed out that as a result of the selectivity afforded in the classification and filing system, it was possible to make the sort of Group 2 using only the random number obtained from the appropriate subdivision of Main Topic 2 of the NACE subject filing index and the sort of Group 3 using only the random number obtained from the appropriate subdivision of Main Topic 3. The various groups under 4, 5, and 6 were sorted for all three random numbers. The results of this search are shown in Table 6. Of 29 pertinent cards obtained, 27 were from the four groups initially selected for sorting. The amount of time required for this search was about 1 hour, and a total of 2,185 cards was handled.

General Use of Classification and Filing System

The above examples illustrate the mechanics of

TABLE 5—Results of Search for Abstract Cards on Accelerated Corrosion Tests for Use With Steels, Low Carbon Through Stainless (Example 2)

Groups Sorted	Cards Handled	Cards Dropped	Pertinent Cards
Group 2.....	495	34	29
Group 6.2 (2).....	50	15	15
Group 4.2.....	170	25	6
Group 4.3 (2).....	5	0	0
Group 4.4 (2).....	10	1	0
Group 4.6 (2).....	20	3	1
Group 5.3 (2).....	80	14	8
Group 5.9 (2).....	25	4	1
Totals.....	855	96	60

making a complete literature search using the classification and filing system with the random-number codes of the NACE subject filing index. It is also apparent that the classification and filing system permits filing of the most important references in a very logical arrangement, so that a quick check can be made without reference to elaborate indexes or random-number codes.

As a further application U. S. Steel is using the same classification and filing index as the basis for filing copies of laboratory data and reprints of technical literature. It is the company's practice to classify all material received for filing according to the NACE subject filing index and then to file it on the basis of the classification and filing index. In this way it is very easy to make a rapid check of the reprint file to determine whether pertinent reprints are on hand which will supplement the findings of the abstract-card search. Classification of material for the literature file is based on the NACE filing index to permit the eventual preparation and punching of abstract cards for insertion in the punch card file.

About three-fourths of the company's total of 8,000 cards are filed under Main Topics 4, 5, and 6. Most of the specific sub-groups under these Main Topics contain less than 100 cards, although in a few instances such as under 6.2(3) there are a few hundred cards. Even in the more elaborate search described above less than one-third of all the cards were handled, and in most searches it is found that less than 15 or 20 percent are handled.

It has been stated that hand-sorted punched-card techniques lose their effectiveness when more than four or five thousand cards must be handled. The selectivity afforded by U. S. Steel's classification and filing system obviously greatly expands the total number of cards which can be accommodated. It is believed that for the usual type of search which is made it will be possible to accommodate at least five or six times as many abstract cards as are now on hand (that is to say 40,000 to 50,000 cards) without having to handle more than 5,000 cards per search. Certainly 25,000 to 30,000 abstract cards can be handled very readily. It is the company's intent to review the situation after approximately 15,000 cards are collected to consider the advisability of punching the cards according to the NACE reference date code or of recommending that the color of the cards be changed every five years to facilitate periodic separation of the older abstracts from the active files.

In making literature searches a comparison has been made of the effectiveness of using the abstract cards and the Bibliographic Surveys. Although the survey volumes have certain advantage of cost, portability, and storage space and serve a very useful function when only an occasional search must be made, the corrosion-abstract punch cards are far more desirable where frequent and rapid searches are required. The additional initial cost is negligible in

TABLE 6—Results of Search for Abstract Cards on Stress-Corrosion Cracking of Stainless Steels (Example 3)

Groups Sorted	Cards Handled	Cards Dropped	Pertinent Cards
Group 2.....	495	63	6
Group 3.....	695	134	8
Group 3.2 (2).....	50	6	3
Group 6.2 (3).....	370	34	10
Group 4.2.....	170	5	1
Group 4.3 (2).....	5	1	0
Group 4.3 (3).....	25	2	0
Group 4.3 (6).....	200	5	1
Group 4.4 (2).....	10	0	0
Group 4.4 (3).....	10	2	0
Group 4.4 (6).....	50	0	0
Group 4.6 (2).....	20	2	0
Group 4.6 (3).....	35	2	0
Group 4.6 (6).....	50	3	0
Totals.....	2185	259	29

view of time saved by their use, and the storage problem is definitely not a serious one since 20,000 cards can be stored in a standard six-double-drawer filing cabinet for 5 x 8 cards. Undoubtedly the biggest advantage of the cards over the surveys is that the pertinent abstracts can be so easily handled and studied by the engineer without the need for copying or taking notes from the survey volumes.

Summary

A method has been developed for the classification and filing of abstracts of corrosion literature based on the NACE abstract filing index and using the NACE corrosion-abstract punch cards. The authors believe that with this classification and filing system all of the original advantages of the NACE punch card system are retained and greatly extended. Furthermore, they believe it should be possible to handle at least 40,000 to 50,000 cards in one filing system rather than the 4,000 to 5,000 cards which normally is the maximum number that can be handled effectively by hand-sort methods. They believe also that this system can be very useful to most companies concerned with corrosion problems related to construction and fabrication or plant maintenance and can be successfully used for filing not only the NACE corrosion-abstract punch cards but also abstracts from any source and copies of laboratory data and reprints of technical literature.

Bibliography

- Lorraine R. Voight. Punched Cards for Filing Corrosion Test Results. *Corrosion*, 4, No. 12, 582-589 (1948) Dec.
- Punch Cards Are Latest Abstract Service to Be Provided by NACE. *Corrosion*, 7, No. 7, 211 (1951) July.
- Ivy M. Parker. The Literature on Corrosion. *Corrosion*, 7, No. 12, 450-453 (1951) Dec.
- Marjorie R. Hyslop. American Society for Metals. Cooperative Information Processing in Metals. Prepared for presentation at Conference on Practical Utilization of Recorded Knowledge, Western Reserve University, Jan. 17, 1956.
- Mars G. Fontana. *Corrosion. Ind. & Eng. Chem.*, 48, No. 7, 75A-76A (1956) July.
- R. A. Fisher and F. Yates. Statistical Tables. Published by Oliver and Boyd (Edinburgh) 1938.



TECHNICAL COMMITTEE ACTIVITIES

Gulf Offshore Structures Valued at \$150 Millions

More Answers Sought on Corrosion Control In Wells With 5000 psi Tube Pressure

Unit Committee T-1B on Condensate Well Corrosion has reported to the parent committee T-1 that the main interest of the committee now has to do with the extremely high pressure gas wells. These are wells with flowing tube pressures over 5000 psi originally considered no different from other gas condensate wells or at least not radically different.

Some operators originally reported as inadequate the same control methods satisfactory with wells flowing at 3000 to 4000 psi. Because of the high pressures all operators are looking for higher strength materials and designing installations primarily with respect to the required pressure ratings, corrosion control receiving secondary consideration.

It has been reported to the committee that many operators are using 9 percent nickel or 9 percent chromium tubing string and that difficulty has been experienced with both. There have been several reports of failure of the 9 percent nickel when the wells produce salt water. Failure of the 9 percent chromium materials has been reported apparently to be a result of stress corrosion cracking or deficiencies in physical properties. Other operators have used a

baked plastic tubing coating with reasonably good success although localized failures have been reported.

There also are operators who depend on inhibitors just as in the lower pressure fields. It has been reported that results from chemical treatment have not been as uniformly effective as in the lower pressure fields. In effect, the most effective method of controlling corrosion in these high pressure gas condensate wells is undetermined.

The committee reports that from an operational standpoint reporting cost of corrosion control in high pressure wells on a cost per year per well basis appears to be more realistic than actual cost per million or billion cubic feet of gas produced. It suggested that cost figures include the actual cost of chemicals per treatment; labor for applying chemicals; cost of evaluation of results, including water analysis or caliper surveys and eventual cost of replacement; the loss of production from down time, although this contributory cost item is difficult to estimate definitely.

Thinking on future work to cope with the high pressure condensate well corrosion problem is not yet crystallized.

Over 450 Units Are Now Operating Committee Says

Unit Committee T-1M on Corrosion of Oil and Gas Well Producing Equipment in Off Shore Installations reports more than \$150,000,000 in equipment and installations is in use for offshore drilling in the Gulf of Mexico. This investment is increasing rapidly. The equipment includes 143 stationary platforms; 300 one-well protective structures; 10 mobile deep water drilling units (14 more on order or under construction); 34 drilling tenders (11 on order or under construction) and a large fleet of personnel boats, cargo boats and barges.

A recent survey by T-1M indicates that industry-wide, the cost for protective coating, cathodic protection and other corrosion mitigation measures was \$4,500,000 in 1955. If activity offshore increases at the present rate, this cost may double in 1956.

Some \$2,000,000 was paid in 1955 for protective coatings on platforms alone. About 250,000 lb. of Monel sheathing was used on platforms for splash zone protection. Cathodic protection is being installed and maintained by all operators on permanent platforms and pipe lines and the use of cathodic protection on marine vessels is expected to increase as better design techniques are developed.

Unit Committee T-1M was created in 1954 in an effort to reduce the mushrooming cost of offshore corrosion control. Four Task Groups have been organized: T-1M-1 on Questionnaires and Screening; Task Group T-1M-2 Protective Barriers; T-1M-3 Cathodic Protection and T-1M-4 Structural Design.

The task group on protective barriers has prepared a composite of coating specifications for marine environments. The specifications are a compilation of specification phrases drawn from present offshore operators' specifications and from other sources. From the composite the user may withdraw the phrases that suit his purpose best. Detailed specifications and qualified inspectors have been found to pay dividends in lasting coating protection.

Design of offshore structures has improved somewhat through experience gained over the past nine years. Some major lessons are just beginning to be considered. These are grouped into three categories by the task group on structural design.

1. Reduction of surface area in all parts of the structure (some operators' design allows two or three times as much area as others with a corrosion cost factor increased proportionately).
2. Elimination of hard-to-coat areas and provisions for easy maintenance.
3. Protection against mechanical damage to coatings and to the platform itself.

(Continued on Page 78)

Sour Oil Well Unit's Attention Focused On Vapor Space Damage, Good Reports

NACE Technical Unit Committee T-1D was organized originally as Sub-Committee TP-1D early in 1950. The objective of the committee was and is to accumulate and analyze data on sour oil well corrosion to determine the extent of the problem and disseminate information on likely methods of control. The committee has carried on a study of field operations through two groups in different geographical areas. These are the West Texas-New Mexico and the Western Kansas areas. These groups have held meetings from time to time, accumulated information by circulation of questionnaires and have reported their findings to the Unit Committee T-1D. In 1954 Task Group T-1D was organized for the purpose of studying the fundamentals of corrosion. The first meeting of this task group was held in Chicago in March 1955. The second meeting was held in New York in March 1956.

Results of a preliminary survey of the sour oil well corrosion problem were presented as a committee report early in 1952. The report was published in CORROSION, August 1952 issue. At that time the following conclusions were drawn from results of the survey:

1. Corrosion is more severe in sour crude wells in the Arkansas and Kansas areas than in sour crude wells in the West Texas-New Mexico area.

2. In general, rods, pumps and the inside of tubing are the items of sub-surface equipment most severely corroded.
3. Corrosion of rods, pumps and tubing in sour crude wells can be substantially reduced by mitigation methods presently available.
4. Corrosion inhibitors are considered by most operators to be the most efficient method of control. A summary of remedial measures was incorporated in the report so that remedial measures with some record of success would be known generally.

In general the conclusions reached in the 1952 report still hold. The summary of remedial measures should still be useful. The principal change has been a shift of emphasis from one type of problem to another. For example, internal casing corrosion in the vapor space of sour crude wells is now a problem of primary importance. Corrosion of rods and tubing is being handled very satisfactorily in most areas with inhibitors and less committee time is being spent on this subject.

In many cases the corrosion of pumps has not been reduced in a satisfactory manner by the use of inhibitors so much work remains to be done. The widespread use of corrosion inhibitors apparently has reduced the number of

(Continued on Page 78)

Joy Heads West Coast Asphalt Coatings Unit

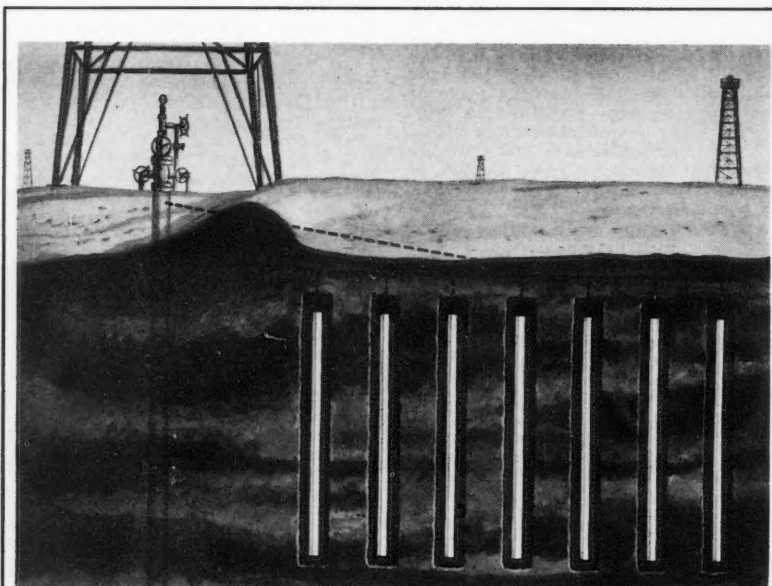
Austin S. Joy, Pipe Linings, Inc., Wilmington, California has been elected chairman of Unit Committee T-2H on Asphalt Type Pipe Coatings. He succeeds R. J. Schmidt, California Research Corporation, San Francisco who had been chairman since the committee was formed in 1954. Mr. Joy has been a member of NACE since 1948 and has been identified with corrosion prevention sales promotion continuously for eighteen years.

Unit Committee T-2H has completed tentative drafts of three reports. They are: Tentative Recommended Specifica-

tions for Asphalt Type Protective Coatings for Underground Pipe Lines, Minimum Recommended Protection; Tentative Recommended Specifications for Asphalt Type Protective Coatings for Underground Pipe Lines, Wrapped Systems and Tentative Recommended Specifications for Asphalt Type Protective Coatings for Underground Pipe Lines, Mastic Systems. After review by committee members they will be submitted for publication in CORROSION.

The Corrosion Abstract Punch Card Service provides about 2000 abstracts a year from 28 abstracting agencies printed on double-row McBee cards.

Public libraries may subscribe to CORROSION at \$4 a year.



OIL WELL CASING PROTECTED FROM EXTERNAL CORROSION

Magnesium anodes are now being used effectively to stop external corrosion on oil and gas well casing. Here's how one major oil company used this low-cost method on 130 wells, 5000 feet deep.

CSI engineers, who helped develop the method, provided a complete turn-key job. They first surveyed the wells, using special surface instruments, to determine the current density required for cathodic protection. Then they installed DOW magnesium anodes using CSI equipment and trained personnel. The installation was designed for a 10 year life.

CSI offers expert consultation and installation services, as well as a complete line of brand-name cathodic protection materials—for both anode and rectifier jobs.

Call or write for competitive cost estimates or quotations. Ask about the new Dow "Galvomag" which gives 20 to 35 per cent more current output than other anodes of similar size.



**CORROSION SERVICES
INCORPORATED**

Tulsa, Oklahoma

P. O. Box 7343, Dept. K6

Telephone: Circle 5-1351

Gulf Offshore Structures—

(Continued from Page 77)

Operators have been slow in developing and making provisions to protect their offshore structures against damage from boats and barges.

In the critical splash zone where maximum corrosion rates may be experienced, plain carbon steel has a corrosion rate of 20 to 30 mils per year. Protective barriers are ineffective unless protected by bumpers, fenders, dolphins or rubber strips from abrasion damage. T-1M heard further reports from task groups at its meeting during the South Central Region Meeting in San Antonio in October.

Sour Oil Well—

(Continued from Page 77)

flow line failures considerably. Plastic pipe and plastic lined steel pipe, cement lined steel pipe and cement asbestos pipe are still in use in some areas but apparently comprise only a small part of the flow line footage.

An item not included for discussion in the 1952 report has received considerable attention from the committee in the last two years. This is the problem of corrosion of steel storage tanks. Excellent opportunities for inspection of interior surfaces of tanks have been afforded committee members at the Permian Basin Section's Tank Inspection tours. Numerous types of protective coatings have been applied by operators and results reported to the committee. It is apparent that no overall method for reducing tank corrosion can be outlined at present. In some areas the under side of the deck suffers severe corrosion while the bottom and sides corrode very little. In other areas the bottom or sides are completely penetrated and the top is found to be relatively undamaged.

The tank suggested by field test results would have an aluminum deck and aluminum top ring, a cone bottom and a suitable protective coating on the bottom and lower 18 inches of the inner wall. Experience shows that not all of these features are needed for all areas.

Discussions at several meetings of T-1D have emphasized the importance of keeping good records especially where tests of inhibitors, coatings, alloys or other materials are in progress or are to be run at a later date. Simplified forms for recording information are used by many operators. The importance of training the field foreman on what to look for and to report it properly has been brought to the committee's attention. The failure of a piece of equipment is frequently investigated by field personnel only and a verbal or written report is furnished the corrosion engineer. From the report he must judge whether the failure was caused by corrosion and what mitigative measures should be taken if any. The reporting of a "rod job" could lead to the conclusion that a sucker rod broke as a result of corrosion when actually the operation could result from a suspected pump failure. If a "tubing job" is reported with no amplification, it would be difficult to determine the nature of the failure if any—whether the tubing failed by splitting in one or more joints, by perforation from rod wear or by parting completely.

res-
(77)develop-
to protect
st damagene where
y be ex-
as a cor-
per year.
ctive un-
fenders,
abrasion
r reports
ng during
eeting in

(77)

y. Plastic
e, cement
asbestos
areas but
small partDiscussion
consider-
tee in the
problem of
ks. Excel-
on of in-
been af-
the Per-
nspection
ective
operators
committee.
l method
n be out-
areas the
rs severe
and sides
areas the
ely pene-
to be rela-I test re-
deck and
ttom and
the bot-
the inner
not all of
all areas.
tings of
importance
ly where
alloys or
ss or are
Simplified
ation are
importance
n what to
perly has
e's atten-
of equip-
l by field
or written
ion engi-
st judge
d by cor-
measures
reporting
e conclu-
s a result
operation
ed pump
reported
be diffi-
ce of the
ing failed
joints, by
y parting

**Cut costly equipment replacement with the DOWELL inhibitor
that can virtually end corrosion!**

CORBAN

Corrosive well fluids can cost an operator plenty . . . in equipment replacement and lost production . . . if his well is not fully protected. Yet many an operator has greatly improved his profit picture by a program of well treatment with Corban®.

A polar-type inhibitor, Corban is available in several formulas to meet different well conditions. Passing freely through valves, it coats metal surfaces with a protective film that can virtually eliminate corrosion. In either

liquid or stick form, Corban is easy to use . . . does not add to emulsion problems.

Try Corban. Test the effectiveness of this Dowell-developed product yourself. Measure, and benefit from, the long equipment life Corban can bring you.

To buy Corban, or for more information, call any of the 165 Dowell offices in the United States and Canada; in Venezuela, contact United Oilwell Service. Or write Dowell Incorporated, Tulsa 1, Oklahoma, Dept. K-77

services for the oil industry



A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY

Oil String Casing Committee Continues to Receive Reports on Corrosion Control Tests

Unit Committee T-1H on Oil String Casing Corrosion continues to receive reports of tests carried out by individual members of the committee. Interest in the subject is at a high level with respect to the mitigation of both internal and external corrosion. Cathodic protection to reduce external casing corrosion is becoming widespread and accepted and is reported to have been installed on more than 1000 wells.

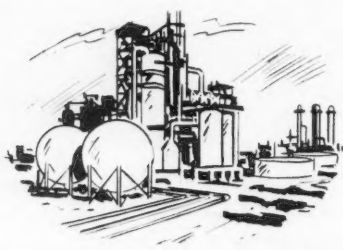
At the meeting of Unit Committee T-1H held in Houston in October, 1955 it was reported that plans were being made to apply cathodic protection to approximately half the wells in a 350-well block to permit a 5-year statistical study of results. Installation of the equipment is well under way and should be completed soon. Similar installations have been or are being made by other companies.

The Western Kansas Task Group of T-1H has been actively studying corrosion problems in the Hugoton area. These studies indicate the area should be watched closely in the future for indications of an increasingly serious problem. It also is established that casing leaks in the area frequently result in the loss of a well or reduction in production. The chairman of the task group has reported cooperative efforts among operators and indicated reasonably good correlation between down-the-hole casing potential profiles and surface potential measurements. It also was pointed

out that there is a possibility of interference from nearby cathodically protected structures.

The West Texas-New Mexico Task Group of T-1H has reported on a lengthy discussion of control measures involving the use of volatile and filming inhibitors. The group reported that several companies are injecting anhydrous ammonia into the casing tubular annulus using 25 lb. treatments at quarterly intervals. Other companies are treating with 50 lb. treatments annually. Although results are reported to be inconclusive to date, recent caliper surveys indicate no increase of corrosion between treatments. Filming type inhibitors are widely used in the area. It was reported that one company batch treats the casing annulus on a semi-annual basis at a cost of approximately \$25 per well.

When Unit Committee T-1H was organized in 1952 it recognized it had undertaken to study a most difficult problem. Everyone was aware that casing corrosion was a serious problem but most operators chose to ignore it where possible because of the obvious difficulties of doing anything about it. Activities of the unit have made it possible for all operators now know where the most serious problem exists. The approximate cost to industry is known and through pooling information it is believed progress has been made in the reduction of failures. At least most feel secure in the knowledge that the recommendations of the committee to management for remedial and preventive measures are based on sound fact. With respect to more specific accomplishments it is believed that through the committee's activity the development of the casing potential log; the surface potential measurement surveys; the widespread application of cathodic protection; and the use of volatile inhibitors such as ammonia in the vapor space of producing wells has been greatly accelerated.



STOP COSTLY CORROSION ON REFINERY TANKS AND LINES WITH "CORECO" RECTIFYING SYSTEMS

Experienced "CORECO" engineers, specialists in design and installation of rectifier and galvanic anode cathodic protection systems, are ready to analyze and solve your corrosion problems.

WHEN YOU THINK OF CORROSION, CALL

"Coreco"
FOR EFFECTIVE
CATHODIC PROTECTION

A Complete Design and Installation Service.
Call, wire or write today to

**CORROSION RECTIFYING
COMPANY**

1506 Zora Street • Houston, Texas

6377

Task Groups to Probe Sweet Oil Well Corrosion

Unit Committee T-1C recently reviewed its history since its founding in January, 1950. Progress was traced with respect to mitigation of both water dependent and water independent types of sweet-oil well corrosion down to the current emphasis on investigation of more specific aspects of the problem. The committee concludes that although progress has been made, much useful work remains to be done. In recognition of the need of further work, the committee has organized task groups designed to investigate experimental and developmental aspects and field practices. A detailed study of statistics of the use of coated tubing in sweet-oil wells also is being planned.

The T-1C-4 Task Group on The Experimental Aspects of Water Independent Type of Corrosion has completed a preliminary report summarizing answers to questionnaires submitted to the task group membership. The questionnaire was designed to gather evidence of

sweet-oil well corrosion resulting from scale deposition and to evaluate the significance of this type of corrosion. Replies were received from five members who indicated the problem probably had been overlooked because of inadequate inspection of equipment. Approximately 3 percent of some 1727 oil wells surveyed indicate severe corrosion is present with equipment most affected was indicated to be tubing and Christmas trees. Corrosion was detected by Caliper surveys and equipment failure. All companies reported that based on available information organic and inorganic acids are the contributory causes of corrosion. It appears that water independent sweet-oil well corrosion is a severe problem limited to certain areas.

Reports from other T-1C Task Groups are scheduled at the committee's meeting in San Antonio in October.

Acceptable Test for Sulfide Corrosion Cracking Sought

NACE Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking has provided two summaries of field experience and collected much additional information. Although the committee has not made formal recommendations as to the desirable methods of preventing stress corrosion cracking, it has circulated information on what other companies are doing and thus encouraged all users of steel products to follow paths that are geared to give greater possibility of trouble free use. This involves emphasis on the selection of materials with minimum susceptibility to cracking. A Task Group of T-1G currently is attempting to standardize

(Continued on Page 82)

Lapel Pins



←
Approx.
Size

Approximately 7/16 inches high, gold, inlaid with bright red enamel background to "NACE" and deep blue enamel background to words "CORROSION CONTROL." Ruby center.

For Association Members Only

\$10

Address Orders to

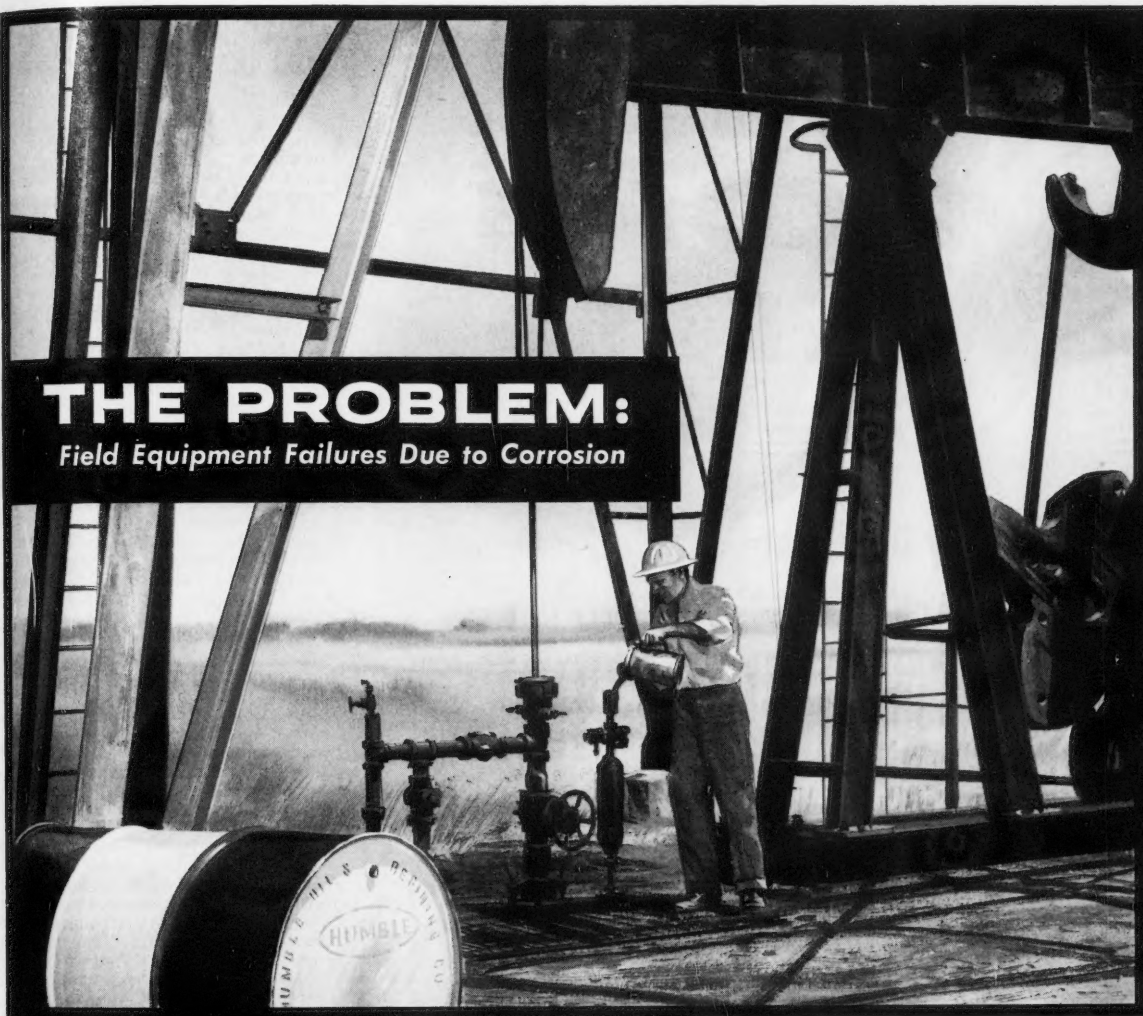
A. B. Campbell, Executive Secretary

**NATIONAL ASSOCIATION OF
CORROSION ENGINEERS**

1061 M & M Bldg., Houston 2, Texas

THE PROBLEM:

Field Equipment Failures Due to Corrosion



THE SOLUTION: Humble's COREXIT—

a Proven Corrosion Preventive

Corexit treatments give sucker rods and tubing positive protection against corrosion and hydrogen embrittlement, even in sour crude wells. Corexit cleans your sub-surface equipment, loosens scale and displaces moisture on the metal surfaces. Then it builds up a tenacious and lasting protective film on these clean metal surfaces to prevent further corrosion.

You will find lifting costs lower when you use Corexit because fewer well pulling jobs are necessary, and the life of your equipment is prolonged.

For complete information on Corexit, see your nearest Humble wholesale plant in Texas and New Mexico, or write or phone: Technical Service, Sales Department, Humble Oil & Refining Company, P. O. Box 2180, Houston 1, Texas.

HUMBLE

HUMBLE OIL & REFINING COMPANY



**for Heavy Duty Maintenance Protection
in Severe Corrosive Atmosphere**

PHENOLINE 305

**a 2-coat, 12-mil maintenance coating
for structural steel, equipment exteriors
and concrete floors**

- Gives **POSITIVE** protection against vapors and splash of most inorganic acids, solvents and caustics. Particularly effective against hydrochloric acid and caustic-chlorine atmospheres.
- 85% solids gives non-porous film.
- Lowers application costs, reduces cost per sq. ft. per year of service.
- Apply over sandblasted or wire brushed surfaces.

USE CARBOLINE'S ENGINEERING APPROACH

WRITE FOR
Carboline's comparative
data chart to figure cost per sq.
ft. per year of service for any system.
Also complete data on Phenoline 305.

**SALES OFFICES in New York, Philadelphia, Detroit, Chicago,
Houston, San Francisco and other leading cities.**

carboline
C O M P A N Y

A Division of Mullins
Non-Ferrous Castings Corporation

**Specialists
in Corrosion Resisting
Coatings and Linings**

327 Thornton Ave., St. Louis 19, Mo.

Coatings Application Group Organized at Los Angeles

The Technical Practices Committee has approved formation of a new NACE Committee, T-6J Los Angeles Area Committee on protective coating application problems. The scope of the new committee is as follows: To discuss, study, report and submit for publication information on protective coating application including specification writing, application procedures, inspection techniques and the establishment of a basis of the acceptance of coating application.

Officers of the new committee are Ivan Sullivan, Spence & Sullivan, Inc., Torrance, California, chairman; F. M. McConnell, Services Coating Corporation, Wilmington, California, vice-chairman and W. M. Jackway, Bechtel Corporation, Los Angeles, California, secretary. There are already 51 members on the committee which holds monthly meetings to discuss progress.

The following task groups have been organized to consider specific problems: T-6J-1 Specification Writing; T-6J-2 Application Procedure; T-6J-3 Inspection Techniques and Application Acceptance; T-6J-4 to Establish a Standard of Cost Evaluation.

Acceptable Test—

(Continued from Page 80)

test procedures which will be acceptable generally and will be recognized as a committee test procedure for testing the susceptibility of steels to crack when exposed to hydrogen sulfide.

Another activity of the committee has been to conduct field tests. These have a dual function: 1. Evaluating field test procedures and 2. Determining what the influence of field environments. The committee has completed two field tests in the McCamey Field.

The other major activity of T-1G involves sponsoring a university research project on sulfide stress corrosion cracking. This project was initiated four years ago at Yale University under the direction of Prof. W. D. Robertson. The project was undertaken to study fundamental metallurgical factors involved in the cracking of steels in hydrogen sulfide environments. Final report on the university research work has been completed and submitted to the committee. After reviewing the report, the committee expects to submit it for publication.

The Corrosion Abstract Punch Card Service provides about 2000 abstracts a year from 28 abstracting agencies printed on double-row McBee cards.

Topical indexing of the cards supplied by the NACE Corrosion Abstract Punch Card Service is pre-punched.

**Write for Information
about the NACE
Abstract Punch Card
Service. Learn how to
save time in
literature searches.**

Group
eels

Committee
w NACE
es Area
ng appli-
the new
discuss,
ublication
ng appli-
writing,
on tech-
f a basis
plication.
ittee are
an, Inc.,
; F. M.
Corpora-
a, vice-
Bechtel
California,
51 mem-
h holds
gress.
ave been
problems:
T-6J-2
Inspection
Ac-
Stand-

ceptable
ed as a
sting the
ck when

ittee has
ese have
field test
what the
ts. The
eld tests
of T-IG
rsity re-
corrosion
ted four
nder the
son. The
y funda-
olved in
gen sul-
on the
en com-
mittee.
commit-
lication.

h Card
stracts a
s printed

supplied
Abstract
ched.



NACE NEWS

Coatings Plan Keyed to Edge-Plane Failure Ratio

Good Records Are Called Essential For Best Results

The ratio of time between edge and plane surface failure of painting systems figures prominently in the maintenance painting systems at Diamond Alkali Company's Houston plants. John Weis, maintenance engineer in charge of coatings for Diamond's plant since July, 1956 told members of Houston Section October 9 his company's system is based on systematic inspection and complete records.

More than 70 members and guests were present at the dinner meeting to hear Mr. Weis and learn from C. L. Woody, United Gas Corp., Houston, section chairman, that the November 13 meeting would be the annual student night.

Mr. Weis outlined general procedures followed at his plant involving inspection and a system providing for periodical reminders of inspection times. Forms used for these purposes were shown.

Ratio Is Significant

The ratio between times to failure of edge and plane painted surfaces is important in the general concept of painting and repainting schedules, Mr. Weis said. The ratio theorem developed through research conducted by Kenneth Tator Associates has been accepted tentatively as an important factor in Diamond's maintenance program. Ratios vary between 2.1 and 3.2 for exposures of varying severity at the plant.

All testing is done on the Kenneth Tator coupon, Mr. Weis said, experience with it having proved it a reliable tool. Numerous testing stations are maintained throughout the plant and regular examinations are made of systems exposed. Testing stations are maintained also at other Diamond Alkali plants. Unprotected steel panels are exposed to determine the basic corrosion rate, which varies from negligible at the company's Dallas plant to virtually complete destruction in two years at the company's Greens Bayou plant, he said. One year's test showed a panel dropped from 762 to 291 grams at this latter location.

Uses of Records Explained

Uses for maintenance painting records in addition to their primary purpose were explained. Mr. Weis said data accumulated on test records could be used as a basis for budget estimates. He emphasized the value of complete records in making it possible for management to distribute painting funds so that areas with worst environments would get the largest sums. When economic conditions force cutbacks, he suggested, plants where corrosion losses are negligible could be cut most drastically and funds for corrosive locations increased



HOW TO TELL WHEN TO REPAINT was the principal point made by John Weis, maintenance engineer for Diamond Alkali, Houston before Houston Section NACE.

as a means of protecting investments in capital equipment.

Galvanizing Is Favored

Mr. Weis, in answers to questions from his audience said also that steel in a projected plant expansion is expected to be galvanized before erection and that the steel will be exposed unpainted until the galvanizing appears nearly consumed. Then, he indicated, the metal would be painted, taking advantage of the excellent coating base provided by the weathered zinc.

Tests of galvanized sign posts in Houston plants show favorable results he indicated, including areas sprayed with zinc to repair surfaces damaged by welding.

Among the other points made by Mr. Weis were:

The nation's painting bill can be estimated today at \$2,280,000,000.

A good maintenance painting program is designed to select the time for repainting or touching up a surface as that on the paint life curve indicating accelerated corrosion damage is beginning. Painting before this point is wasteful because it is unnecessary and painting afterward costly because it involves excessive surface preparation expenditures.

After testing 40 generic types of coatings and compiling 900 case histories Diamond Alkali has concluded its paint system in use is the best economically.

LaQue Talks at Los Angeles

F. L. LaQue, The International Nickel Co., Inc., New York spoke on "What Keeps Metals from Corroding Faster" at a September 20 meeting of American Society for Testing Materials, American Society for Metals and Los Angeles Section NACE. About 300 members and guests of the three organizations attended.



NACE MEETINGS CALENDAR

Nov.

- 1 Pittsburgh Section. Fundamentals of Corrosion, R. H. Brown, Alcoa Laboratories, New Kensington, Pa.
- 5 North Texas Section. Pipeline Corrosion, John W. Pool, Magnolia Pipe Line Co., Dallas and Ralph G. Petty, Sinclair Pipe Line Co., Fort Worth.
- 7 (or 14) Niagara Section. Coatings and election of officers.
- 8 Sabine-Neches Section. Review of papers presented at San Antonio South Central Region Meeting. Little Mexico Restaurant, Orange, Texas.
- 13 San Francisco Bay Area Section. Carbon and Graphite—Their Place in Corrosion Control, W. W. Palmquist, National Carbon Co.
- 15 Kanawha Valley Section. Corrosion of Tin and Tin Alloy Coatings, F. A. Lowenheim, Metal and Thermit Corp. Kanawha County Airport, Charleston, W. Va.
- 19 Lehigh Valley Section. Power plant corrosion, W. Z. Friend, International Nickel Co., Inc. New York. Keystone Trail Inn, Allentown, Pa.
- 20 Chicago Section. Protective Coatings, Their Behavior and Why, H. F. Haase, Milwaukee.
- 20 San Diego Section. (Tentative)

Dec.

- 3 North Texas Section. Design for Corrosion Control, F. L. Whitney, Jr., Monsanto Chemical Co., at Dallas.
- 5 New England Section. Corrosion in the Home, J. T. Kemp, American Brass Co.
- 6 Pittsburgh Section. Corrosion of Metals, W. Z. Friend, The International Nickel Co., Inc. Mellon Institute.
- 6 Sabine-Neches Section. My Corrosion Problem of the Year, a panel discussion. Little Mexico Restaurant, Orange, Texas.
- 13 Philadelphia Section. F. L. LaQue, The International Nickel Co., Inc. scheduled speaker. Poor Richard Club, Philadelphia.
- 13 Detroit Section. Sprayed Coatings—Metallic and Non-Metallic, R. J. McWaters, Metallizing Engineering Co., N. Y.

Rosemary B. Smith Joins

NACE Abstract Committee

Miss Rosemary B. Smith, The International Nickel Co., Inc., has joined the Abstract Subcommittee of the National Association of Corrosion Engineers.



AMONG THE 190 OR MORE PERSONS participating in Shreveport Section's Sixth Annual Corrosion Control Short Course at Centenary College, Shreveport September 20-21 were (left to right) Jim Butler, Arkansas Louisiana Gas Co., mail and publicity co-chairman; John Wise, Arkansas Louisiana Gas Co., program chairman; W. F. Fair Jr., Koppers Co., NACE president; Gaston V. Jones, Arkansas Louisiana Gas Co., Shreveport Section chairman and Lionel Morrow, Interstate Oil Pipe Line Co., general chairman of the course.

Tin Corrosion Is Topic for Kanawha Valley Section

"Corrosion Behavior of Tin and Tin Alloy Coatings," will be the subject of the November 15 technical talk before members of Kanawha Valley Section at Kanawha County Airport, Charleston, W. Va. F. A. Lowenheim, Research Laboratory, Metal and Thermit Corp., Rahway, N. J. will be speaker.

The scheduled topic at the September 20 meeting at Marietta Country Club, Marietta, Ohio was "The Uses of Polyethylene and Polystyrene in the Chemical Industry," by E. B. Westlake, Jr., president, Westlake Plastic Co., Lenin Mills, Pa.

Other meetings and topics scheduled are:

Jan. 17—Corrosion Resistant Steels for Industry, John J. Halbig, Research Laboratories, Armco Steel Corp., Middletown, Ohio, Ashland, Ky.

March 28—Summary report on the

Kanawha Valley Coordinating Committee on Corrosion, followed by a round table discussion on cathodic protection and its applications. Kanawha County Airport, Charleston, W. Va.

May 16—Titanium—Fabrication and Corrosion Resistance, William Lusby, Pigments Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. Topette Drive-In, Route 60.

Greater St. Louis Section Elects George T. Shutt

The following officers have been elected for 1956-57 by Greater St. Louis Section: George T. Shutt, Shutt Process Equipment Company, chairman; Charles W. Ambler, American Zinc, Lead & Smelting Company, vice-chairman; Oliver W. Siebert, Monsanto Chemical Company, secretary and Wallace C. Philoon, Mallinckrodt Chemical Works, treasurer.

Los Angeles Corrosion Course Program Given

Program of the November 13-14 course "Practical Considerations of Underground Pipe Corrosion for Non-Technical Personnel" at University of California, Los Angeles has been given as follows:

November 13

- 9 am—Introduction, P. W. Hill, Signal Oil and Gas Co., Long Beach, Cal.
- 9:15 am—Fundamentals of Pipe Corrosion and Its Control, Harry J. Keeling, Los Angeles, Cal.
- 10:45 am—Use of Coatings in Corrosion Control, S. K. Gally, Southern California Gas Co., Los Angeles.
- 1:30 pm—Pipeline Construction and Corrosion Control, V. A. Barnato, General Petroleum Corp., Los Angeles.
- 2:45 pm—Corrosion Control With Galvanic Anodes, W. M. Schilling, Southern Counties Gas Co.

November 14

- 9 am—Corrosion Control With Impressed Currents, D. N. Markoff, Consulting Engineer.
- 10:30 am—Cathodic Interference, R. I. Stark, Pacific Gas and Electric Co., Bakersfield, Calif.
- 1:20 pm—Question and answer session, all authors.



**NATIONAL, REGIONAL
MEETINGS and
SHORT COURSES**

1956

- Nov. 8-9—Southeast Region Fall Meeting, Charlotte, N. C.
- Nov. 15-16—North Central Region Meeting, Detroit, Mich.
- Nov. 15-16—Western Region, Long Beach, Cal.

1957

- Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri.
- May 20-22—Northeast Region Corrosion Control Conference, Syracuse University, Syracuse, N. Y.

1958

- Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

1959

- NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

SHORT COURSES

1956

- Nov. 13-14—University of California at Los Angeles—Western Region.

1957

- January—Houston Section—University of Houston Short Course on Corrosion.

- April 2-4—University of Oklahoma, Norman and Central Oklahoma Section NACE.

New transistorized Soil Resistivity Meter

... gives on-the-spot measurements
in ohm/cm³

• **TRULY PORTABLE—ONLY 3 1/4 LBS.**

Makes soil resistivity data for corrosion studies easy, simple to obtain. New transistorized ALL ELECTRONIC circuit provides AC for accurate measurements. Uses 2 small mercury cell batteries—good for 10-12 months. Also use as AC ohmmeter. Includes 4 ft. probe, leather case.

Also NEW potentiometer voltmeter; NEW transistorized, portable, AC-DC VTVM.



PRICE **\$165.00**

Research Laboratory, Inc.

Manufacturers of M-SCOPE Pipe Finders • Dept. CO-1, Palo Alto, California

Corrosion
given

er 13-14
s of Un-
or Non-
ersity of
en given

l, Signal
, Cal.
e Corro-
J. Keel-

Corrosion
ern Cali-

on and
Barnato,
Los An-

ith Gal-
g, South-

With Im-
off, Con-

e, R. L.
etric Co.,

session,

SIONAL

nd

RSES

ll Meet-

on Meet-

a. Long

nference,
souri.

Corrosion
use Uni-

nference,
co, Cali-

an Hotel,

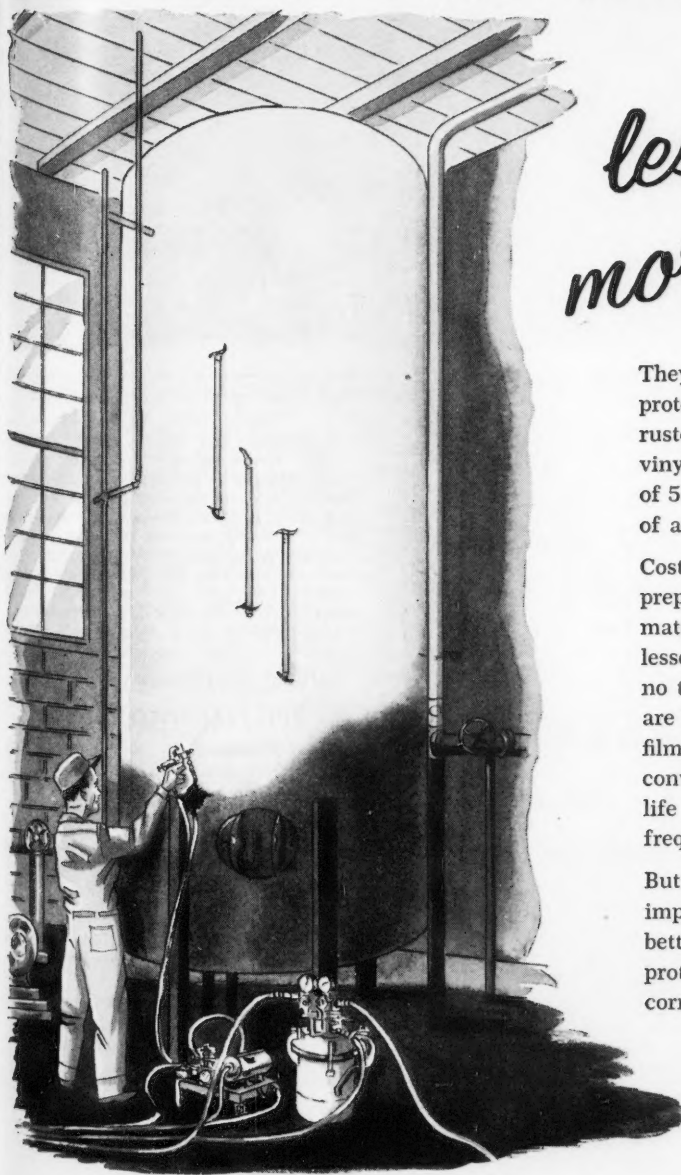
ornia at
on.

niversity
Corro-

na, Nor-
Section



HERE ARE COMPANION PRODUCTS TO MAKE YOUR FIGHT AGAINST CORROSION...



*less costly-
more effective*

They are: Tygorust — a primer that locks protective coatings to damp or dry rusted steel; and Tygon "ATD"* Hot Spray vinyl which builds up a film thickness of 5 mils or better in just two passes of a spray gun.

Cost savings are big. First of all, surface preparation costs are reduced materially. Second, material costs are lessened because Tygon Hot Spray requires no thinners. Third, application costs are lowered because two spray passes give a film thickness equal to five coats of conventionally applied paints. Fourth, longer life means lower maintenance costs, less frequent recoating.

But cost savings are, in a sense, the least important part of the story. You get better protection, more complete protection, longer lasting protection from corrosive attack.

***ADHESION
THICKNESS
DENSITY**

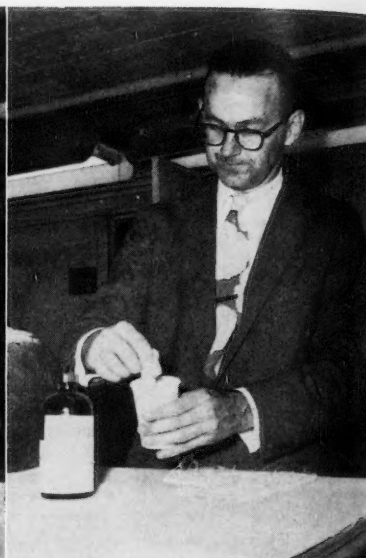
Get the full story today. Write for your free copy of the TYGON painting manual. Address: Plastics & Synthetics Div. U. S. Stoneware, Akron 9, Ohio.

**PLASTICS AND
SYNTHETICS
DIVISION**

208-E



New York • Chicago • Houston



Pipeline, Home Corrosion Discussed at San Diego

The fifty members and guests attending the September 19 meeting of the San Diego Section heard William Schilling, Southern Counties Gas Company and Ruben Tullis, San Diego City Water Dept., present papers on "Cathodic Protection of the Biggest Big Inch Pipe-

line" and "Corrosion in Action" respectively.

Mr. Schilling spoke on the general history of the Big Inch pipeline, covering terrain, length, type of coating and followed with a discussion of soil conditions and trouble spots. Cathodic protection necessary for the line also was discussed. Mr. Schilling pointed out how, after the original installations were made, regular checks made of effectiveness of protection showed in some cases

additional stations were necessary. He also covered reasons for changes in protective requirements.

Mr. Tullis spoke on galvanic couples such as might be found in the home, particularly copper-galvanized pipe couples. Demonstrations accompanying his talk were particularly effective in clarifying the subject for newcomers in the corrosion field. The principal demonstration showed how a small electric motor could be operated from the current generated by a galvanic couple.

Tanker Corrosion Is Topic At San Francisco Session

The 35 members and guests attending the September 18 meeting of San Francisco Bay Area Section heard F. M. Watkins, coordinator of American Petroleum Institute's Tanker Corrosion Project speak on the organization and scope of the API tanker corrosion project including some details about corrosion in tankers and progress the project has made. Mr. Watkins also discussed the most promising methods of corrosion control under consideration by the project.

W. W. Palmquist, National Carbon Company is scheduled to speak on "Carbon and Graphite—Their Place in Corrosion Control," at the November 13 meeting.

Culvert Corrosion Covered At Meeting in Denver

At the September 21 meeting of Rocky Mountain Section at Olin Hotel, Denver, Colorado 45 members and guests heard O. B. Ellis, Armco Research Laboratories, Middletown, Ohio speak on Protective Coatings and the Corrosion Behavior of Culvert Materials. During the meeting past chairman certificates were presented by H. K. Becker to W. H. Schultz and J. E. Fugazzi.

CORROSION's Technical Section is indexed annually in December.

New TOGGLE LATCH makes it a **SNAP** to open

OIL IMMERSED

Good-ALL CATHODIC PROTECTION RECTIFIERS

The new TL appeals to engineers because of its practicality and convenience. TL eliminates the time-consuming job of removing bolts from four sides of the rectifier, then lifting off a heavy top. To change output taps, just snap open the toggle latches (TL) and swing open the hinged top. It's as quick and easy as that. Good-All's new top arrangement makes the rectifier so easily accessible that engineers no longer find it necessary to specify external adjusting taps, thus saving considerable in extra cost. The top is completely weather-proof. There are no bolt holes, and a wide Neoprene gasket prevents dust from entering. Oil immersed units can also be furnished with explosion-proof switches, meters and fittings.

Saves Time-Saves Money

21-L

GOOD-ALL ELECTRIC MFG. CO.

Electrical-Mechanical Div. OGALLALA, NEBRASKA





Philadelphia Section Learns of Versatility, Construction of Glass Reinforced Plastics

Versatility of reinforced plastics was described to Philadelphia Section September 10. Thomas F. Anderson, Havg Industries, Wilmington, Del. explained some of the combinations of reinforcing and plastics used to fabricate a wide variety of process equipment.

He displayed a laminate made with a unidirectional glass fiber mat with a tensile strength in one direction of more than 100,000 pounds per square inch but with only 5000 or 6000 pounds per square inch in the other direction. Other combinations of material with random glass fibers will provide a laminate having 25,000 to 30,000 pounds per square inch tensile strength in all directions.

In compounding reinforced plastics for chemical process equipment, optimum protection of the glass fiber by the resin usually is obtained by using a mat of 20-30 percent glass fibers with random orientation of fibers. This combines good overall chemical resistance and also resists mild physical abuse.

Ordinary installation of ducts and piping is not particularly difficult; 90 percent of it is done by regular plant maintenance crews. Rigid plastic tanks can be made translucent, allowing some degree of observation of processes occurring within them. Tanks up to 12 feet in diameter and 11 feet deep can be made and shipped in one piece. Field installation of large tanks entails exact fitting of joints and seams, Mr. Anderson said and specialists usually erect them.

Cost of chemical grade polyester fiber glass material ranges in price from \$1.50 per square foot per 1/8-inch thickness, up \$2 or \$2.50. Complex fabrication costs about \$3 to \$5 per square foot of 1/8-inch thickness and unusually complicated items cost as much as \$18 to \$20 per square foot.

Central Oklahoma Section

Central Oklahoma Section has scheduled a meeting November 27 at Tropical Cafeteria, Oklahoma City.

Illustrated Lectures Favored By Philadelphia Section

Illustrated lectures, presentation of papers and panels are the leading preferences of Philadelphia Section members as to types of technical presentation, a recent survey showed. The survey was made to determine the preferences of members in several activities related to section operation.

Leading preferences from 118 replies to 303 questionnaires mailed showed also that Philadelphia Section members prefer four meetings a year on Friday with meal in the evening; the practical approach in technical information; organic coatings as a subject matter, fol-

HOW TO REPAIR A FIBERGLASS REINFORCED pipe was demonstrated to members of Philadelphia Section at a September 10 meeting. Thomas F. Anderson, Havg Industries, Wilmington, Del. shows how, left to right: Striking the pipe won't break it but the marks open avenues of attack for fumes to penetrate the plastic and affect the glass itself. First step in repair is to sand the surface to remove dirt and roughen surface. Second step is mixing plastic resins with catalyst. Next step after pouring mixed plastic on starch binder surfacing mat is to brush down fibers. After patch is placed over damaged area additional resin is brushed into it. Finally, using a surfacing mat (later removed) to prevent raising fibers the resin is stroked out to assure a smooth and strong joint.

lowed closely by materials of construction and corrosion mechanism; chemical industry, petroleum and power industry subjects, in that order. Social activities are not liked, with picnics given preference over other forms when social events are held.



for cathodic protection

MAGNESIUM ANODES

Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.

Anode folders or technical consultation with our engineers available upon request.

APEX SMELTING COMPANY

CHICAGO

CLEVELAND

LOS ANGELES

APEX Anodes are available in 17 lb. and 32 lb. bare anode with or without wire, or complete packaged anode with wire and back-fill ready for installation.

NEW TROPOXIES

Have greater
resistance to

CORROSIVE CHEMICALS



Correct Mil Thickness Applied Within Hours

Ordinary paints "give up" when chemicals or chemical fumes attack. New Tropoxy enamels, for both moderate and severe conditions, give long-lasting protection to exterior metal, wood, concrete, plaster, brick, cement or cinder block. They are color-fast, and the ideal 5-mil thickness can be built up within hours.

Protective Coatings for Corrosion Problems

Investigate our oleoresinous phenolics, rubber-base paints and enamels, high-heat (up to 1000°) aluminums. They have been performance-proved on thousands of applications.

FREE—complete information on our specialized industrial coatings sent on request.

TROPICAL PAINT CO.

1142-1218 W. 70th, Cleveland 2, Ohio

Heavy-Duty Maintenance
Paints Since 1883

TROPICAL

SUBSIDIARY OF
PARKER RUST
PROOF COMPANY



Long Speaks at Chicago Section's Ladies' Night

"Scientific Living," was the theme of a talk by Dr. J. S. Long, research consultant for Devco & Reynolds Co., Inc. and formerly chemical director for the company from 1934 until July, 1955. Speaking at the September 18 meeting of Chicago Section before 70 members and guests, he avoided highly technical subjects and aimed his remarks principally at wives, present for the annual Ladies' Night Meeting.



Long

Dr. Long mentioned briefly his work on adhesion using the Langmuir apparatus and his current investigations into the effect of ultraviolet light on paint films. So far, he indicated, there seems to be no correlation between chemical composition and resistance to sunlight, but it has been established that absorbed ultraviolet light causes most of the damage.

The Fellowship Hour was sponsored by The Kendall Co., Polyken Sales Div. Senior host was Dean Crawford with Messrs. P. M. Witzman, P. S. Sikorski, and W. J. Hodges as assistants.

Committee chairmen have been named for the 1957 North Central Region meeting, it was announced.

75 From Three Societies Attend Brockville Session

Seventy-five members of Brockville, Ontario's sections of the Chemical Institute of Canada, Engineering Institute of Canada and the Central New York Section of NACE attended a September 28 meeting at Brockville, Ont. The modern wire and cable plant of Phillips Electrical Co., Ltd. was toured by 25 persons.

Following a buffet supper at Brockville Golf Club, R. J. Law, The International Nickel Co., Inc., Toronto spoke on the aims and history of NACE. He then showed a color motion picture of the Kure Beach and Harbor Island testing stations of Inco.

This was the first meeting of the current season for Central New York Section NACE which includes Syracuse and Watertown, N. Y. and Eastern Ontario, Canada.

Record Registration Is Forecast for San Antonio

Based on 425 pre-registrations on hand October 11 and on reports from San Antonio hotels of more than 1000 reservations a record attendance at NACE's South Central Region meeting October 23-26 was forecast.

No changes in the schedule of technical committee meetings or other programmed events were known by October 15.

Two exhibitors, in addition to those listed in CORROSION's October issue on Page 88 were added as follows: S. E. Boseley Co., and Standard Magnesium Corp., both of Tulsa, Okla.

Five Detroit Section Meetings Scheduled

Five Detroit Section meetings are scheduled after the November 15-16 North Central Region meeting. The meetings and programs are as follows:

December 13—R. J. McWaters, Metalizing Engineering Co., New York, "Sprayed Coatings—Metallic and Non-Metallic."

Jan. 24—Dinner meeting, A. J. Thompson, Allis-Chalmers Mfg. Co., Milwaukee, "Cavitation and Impingement Attack in Pumps."

February 21—Joint meeting with The Electrochemical Society, Milton Stern, Electro Metallurgical Corp., Niagara Falls, "Fundamentals of Electrode Processes in Corrosion."

April 18—Dinner meeting, S. L. Gajownik, Sherwin-Williams Paint Co., Chicago, "Industrial Maintenance Paint Developments." Annual paint meeting.

May 16—Demonstration and lecture on microwaves, transistors and the solar battery, Herbert Bumpus, Michigan Bell Telephone Co., Detroit.

At the September 27 meeting, W. Z. Friend, The International Nickel Co., Inc. spoke on "The Corrosion Engineer's Relationship to Management." This was the L. D. Cook Memorial meeting. On October 25, Harry Howard, Chell Chemical Corp., New York spoke on "Uses of Epoxy Resins for Corrosion Protection."

An alphabetical subject and author index of the CORROSION Technical Section is compiled and published in December.

AMENDMENTS TO NACE ARTICLES AND BY-LAWS

The Articles of Organization and By-Laws of the National Association of Corrosion Engineers were published in the March 1952 issue of CORROSION. Since that time three amendments have been made in the by-laws as follows:

1. At a meeting on March 19, 1954 the board of directors approved an amendment to the NACE by-laws increasing active membership dues from \$7.50 to \$10.00. The amendment, effective January 1, 1955 was to Section 1, Article 11, of the by-laws that became effective March 11, 1951.
2. At a meeting on December 3, 1954 the board of directors approved a recommendation of the Policy and Planning Committee amending Section 2, Article I, of the NACE by-laws that became effective March 11, 1951 as follows:
All Applications for membership shall be forwarded to the Secretary and upon a finding by the Secretary that an applicant's qualifications conform with standards and membership requirements of the Association, membership shall become effective immediately upon payment of dues. If in the judgment of the Secretary, the eligibility of any applicant for membership shall be uncertain, such applicant's application shall be referred by the Secretary to the Executive Committee and an affirmative vote of a majority thereof required for election to membership.
3. The Board of Directors by letter ballot dated April 25, 1956, approved an amendment to the NACE by-laws consisting of the addition of a new paragraph designated as Section 5, Article III, of the By-Laws that became effective March 11, 1951:
Exhibitions held or sponsored by regions or sections shall have the approval of and be under the management of the Board of Directors including the handling of formal contracts with prospective exhibitors and contracts for exhibit space by the Executive Secretary of NACE. The proceeds from such exhibitions shall become a part of the funds of the Association.

1957 Exhibition Brochure Mailed

A brochure describing the principal features of the 1956 Exhibition to be held in connection with the NACE 13th Annual Conference at Kiel Auditorium in St. Louis have been mailed. The exhibition will be held March 12-15.

The mailing list used for the mailing is one compiled over a period of years of past exhibitors and others known to have an interest in corrosion control. Because it is impossible to know the names of all companies likely to be interested in the show Charles G. Gribble, Jr., Metal Goods Corp., Houston and Walter B. Meyer, St. Louis Metallizing Co., St. Louis, exhibit committee co-chairman suggest that those who do not receive the information literature write to the Central Office NACE at Houston, asking to be put on the mailing list.

NACE members or others who believe their companies may be interested in the exhibition are asked to write to Central Office and supply the name and title of the person in their company to whom literature should be sent.

The 1957 exhibit contemplates a maximum of 146 booths.

Corrosion of Welded Joints Discussed by R. D. Thomas

Corrosion of Welded Joints in Piping Systems was the subject of a talk by R. David Thomas, Jr., Arcos Corp. at the September 18 meeting of Philadelphia Section. He opened his part of the program with a sound and color motion picture showing techniques advocated in tungsten inert gas arc welding. Advantages of a type of joint developed by the Electric Boat Division of General Dynamics Corp. were illustrated.

Mr. Thomas also discussed application of this technique to piping for highly corrosive applications under the headings, details of EB Welding Inserts for various piping sizes; mechanical considerations in application, metallurgical considerations and economics.

The 55 members and guests heard Miss Jerri McCormick of Bell Telephone Company's public relations department give a lecture and demonstration on "Magic in Color."

WHERE TO FIND NACE TECHNICAL PROGRAMS

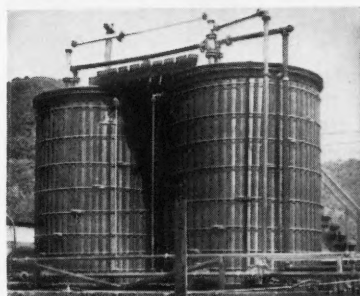
Information on the technical and social programs for NACE regional meetings during November may be found in CORROSION's October issue indicated below:

Southeast Regional Meeting, Page 87.
North Central Regional Meeting, Page 83.
Western Regional Meeting, Page 86.

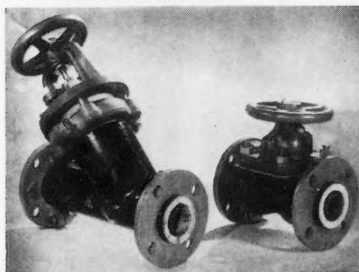


News

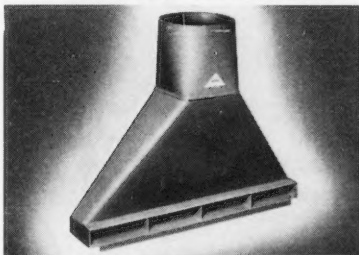
Wherever CORROSION RESISTANCE is a Factor IF CORROSION IS THE PROBLEM HAVEG PLASTICS ARE THE ANSWER!



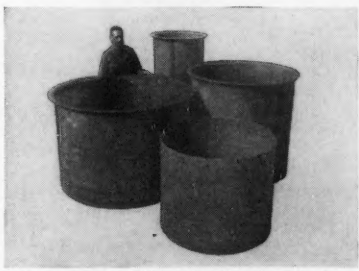
Haveg storage tank installation



Haveg corrosion resistant valves



Large Haveg polyester glass self-supporting fume hood



Haveg light weight polyester glass tanks

Rugged strength and durability . . . exceptional resistance to corrosion . . . longer, trouble-free service at process temperatures as high as 350°F.—you get them all at bonus savings in installation time, material, and maintenance costs with Haveg plastic equipment.

PROCESS PIPE, TANKS, TOWERS, FUME REMOVAL SYSTEMS, DISTILLATION COLUMNS, FILTER PRESS PLATES—wherever industrial equipment is required to handle corrosive materials or atmospheres—Haveg corrosion resistant plastics have solved the problem at leading process plants. In addition to equipment a wide selection of Haveg resin cements offer required chemical resistant properties for extensive use as mortar in chemical brick and tile flooring, equipment lining, etc.

Haveg phenolic, furan, polyvinyl and polyester resins are selectively formulated to provide maximum resistance to the corrosive chemicals used in your particular operations . . . acids, hypochlorites, chlorinated solvents, salts, alkalis, hydrocarbons, and a variety of oxidizing agents. Excellent machining and molding characteristics permit economical fabrication of a wide range of intricate shapes and sizes to meet exacting specifications. Write for illustrated Bulletin C-13.

HAVEG DESIGNS, ENGINEERS, BUILDS YOUR PROCESS EQUIPMENT

Skilled Haveg corrosion engineers, experienced in designing and engineering corrosion resistant equipment for diverse industrial applications, will develop equipment to meet your process needs . . . to assure you full advantage of Haveg's low cost methods. Designed and fabricated to your specific requirements, each Haveg installation is guaranteed to give top process performance! Details of this unusual service are available at no obligation from a qualified Haveg sales representative.

H-602

HAVEG PLASTICS OF TOMORROW SOLVE YOUR CORROSION PROBLEMS TODAY

HAVEG INDUSTRIES, INC.

930 Greenbank Road, Wilmington 8, Delaware
Factory: Marshallton, Del. phone WYman 8-2271

Atlanta Exchange 3821	Chicago (Wheaton) Wheaton 8-3225	Cleveland Washington 1-8760	Detroit (Livonia) KENwood 1-1785	Houston Jackson 2-6840	Los Angeles MUTual 1105	New York (Westfield, N.J.) Westfield 2-7383	Seattle Main 9006	Denver BEImont 7-0433
--------------------------	----------------------------------------	--------------------------------	----------------------------------------	---------------------------	----------------------------	---------------------------------------------------	----------------------	--------------------------

HOSE PROBLEMS?

You need this
TEFLON®
corrosion-proof
hose

- Handles virtually every fluid and gas from -100°F to $+500^{\circ}\text{F}$
- Ageless — and stays flexible indefinitely

SOLVE your really tough jobs for flexible hose with *Fluoroflex®-T* hose assemblies — the original Teflon hose now proved by over 3 years of demanding service.

With tube made from a patented, special compound of Teflon, the hose is completely inert to the most corrosive chemicals, active oils and fuels, gases, steam.

SAE 304 stainless steel braid reinforces for up to 1000 psi service (higher in some cases) and maintains this strength by its corrosion resistance.

Permanent, swaged fittings give positive protection against leakage and blowoff.

These lightweight, space-saving hose assemblies solve tough problems, increase reliability, cut replacement costs. Made by the originator of Teflon hose — the one company that makes its own Teflon tubing as well as the hose assemblies. For more data, write RESISTOFLEX CORPORATION, Roseland, N. J.; Western Plant: Burbank, Calif.

® Teflon: DuPont trademark.

Fluoroflex: Resistoflex trademark.



RESISTOFLEX

Boiler Water Conditions Discussed at Vancouver

Vancouver Section heard F. W. Richardson speak on Boiler Water Conditions September 18. Mr. Richardson covered the boiler water conditioning field, considering problems involved in treating water for super critical steam generators, reduction of oxygen in feed-water and performance of silicates. Sixteen members and guests were present.

Southwestern Ohio Section Tours New Sewage Plant

Following a tour September 25 of the Mill Creek Sewage Plant 21 members and guests of Southwestern Ohio Section heard a short talk by A. A. Burger and A. M. Moch of Havens & Emerson, supplemented by a film showing construction progress of the sewage plant.

\$22 Billion Will Be Spent On Sewage Plants by 1976

Expenditure of over \$22 billions during the next 20 years for new sewerage systems and to offset obsolescence of existing systems is forecast by the Water and Sewerage Industry and Utilities Div., Business and Defense Services Administration, U. S. Department of Commerce, Washington, D. C. Present capital invested in public sewerage facilities is estimated to be \$19 billion.

Public libraries may subscribe to CORROSION at \$4 a year.

CERTIFICATES of MEMBERSHIP in NACE

Certificates of membership in the National Association of Corrosion Engineers will be issued on request at \$2 each, remittance in advance. The certificates, which measure $5\frac{1}{2} \times 8\frac{1}{2}$ inches, are signed by the president and executive secretary of the association.

CERTIFICATES for PAST CHAIRMEN of REGIONS and SECTIONS

Certificates measuring 9×12 inches in size, prepared from an engraved plate, are available for issuance to regional and sectional chairmen. They will be supplied on request of the region or section at \$7.50 each to be paid by the region or section, the cost to be classified as a non-reimbursable expenditure.

Address Orders to

A. B. Campbell, Executive Secretary

NATIONAL ASSOCIATION of
CORROSION ENGINEERS

1061 M & M Bldg., Houston 2, Texas



GENERAL NEWS

Electrochemical Society Session Attended by 900 34 of 110 Papers Were Presented in Corrosion Symposium

About 900 persons registered for the Sept. 30-Oct. 4 110th meeting of The Electrochemical Society in Cleveland. Of the 107 papers scheduled for presentation 34 were grouped in a corrosion symposium. Like other meetings of this society all, or nearly all of the papers, except a few related to battery phenomena are significant to corrosion workers.

Following is the schedule of papers in the Corrosion Symposium:

Tuesday, October 2, High Temperature Oxidation

Oxidation of 50 Weight Per Cent Uranium-Zirconium Alloy, by Sidney Barnartt, R. G. Charles and E. A. Gulbransen

Kinetics of the Oxidation of Chromium, by E. A. Gulbransen and K. F. Andrews

High Temperature Scaling of Cobalt-Chromium Alloys, by C. A. Phalnikar, E. B. Evans and W. M. Baldwin, Jr.

High Temperature Scaling of Nickel-Manganese Alloys, by E. B. Evans, C. A. Phalnikar and W. M. Baldwin, Jr.

Oxidation of Iron-Nickel Alloys, III. Kinetics and Mechanism, by R. T. Foley and C. J. Guare

Tuesday, October 2, Factors Related to Corrosion

Hydrogen Diffusion Through Steel, by T. J. Butler and R. T. Davis, Jr.

Low-Pressure Solubility and Diffusion of Hydrogen in Zirconium, by M. W. Mallett and W. M. Albrecht

Corrosion Characteristics of Uranium. An Electron Diffraction Study, by J. T. Waber and D. D. Whyte

Orientation Factors in Oxide Films on Uranium, by J. T. Waber

Variations of Alkaline Anodizing Baths for Magnesium, by W. McNeil and R. Wick

Potential-pH Diagram of the Antimony-Water System; Its Applications to Properties of the Metal, Its Corrosion, and Antimony Electrodes, by A. L. Pittman, Marcel Pourbaix and N. de Zoubov

Wednesday, October 3, Corrosion Kinetics

Effect of Prior Corrosion History on the Corrosion of Zircaloy-2 in High Temperature Water, by D. E. Thomas and S. Kass

A Reaction Rate Study of the Corrosion of Low-Hafnium Zirconium in Hydrofluoric Acid Solution, by Tennyson Smith and G. R. Hill

Hydrogen Evolution from Dissolving Titanium-Oxygen Alloys in Hydrofluoric Acid and the Constitution of the Ti-O Alloys, by M. E. Straumanis,

C. H. Cheng and A. W. Schlechten
Dissolution of Iron in Hydrochloric Acid-Chromic Chloride Solutions, by Robert Skomoroski and C. V. King
Kinetics of the Reaction of Steel with Hydrogen Sulfide-Hydrogen Mixtures, by A. Dravnieks and C. H. Samans

Kinetic Studies on Alkaline Nitrite Formation of Black Oxide Coatings on Mild Steel, by R. M. Hurd and Norman Hackerman

Corrosion of Austenitic Stainless Steel in Circulating Uranyl Sulfate Solutions at High Temperatures. I—Experimental Results, by E. G. Bohlmann, J. C. Griess, Jr., and R. S. Greeley

Corrosion of Austenitic Stainless Steel in Circulating Uranyl Sulfate Solutions at High Temperatures. II. Mechanism of the Corrosion Process, by J. C. Griess, Jr. and E. G. Bohlmann
Corrosion of Austenitic Stainless Steel in Dilute Acid Solution at High Temperature, by J. C. Griess, Jr., R. S. Greeley, E. G. Bohlmann and S. R. Buxton

An Investigation of the Effect of Chemical Variables on the Corrosion of Copper, by W. D. Robertson, V. F. Nole, W. H. Davenport and F. P. Talboom, Jr.

Corrosion of Single Crystals and Recrystallized Single Crystals of Iron and Steel in Citric Acid, by W. R. Buck, III and Henry Leidheiser, Jr.

Thursday, October 4, Electrochemistry of Corrosion

Anodic Behavior of Cu in HCl, by R. S. Cooper

Stress Potentials for Tension and Torsion Stresses, by W. F. Seyer, O. K. Miniato and K. Nobe

Chemical and Electrochemical Properties of FeSn₂, by R. A. Covert and H. H. Uhlig

Electrochemical Polarization. I—A. Theoretical Analysis of the Shape of Polarization Curves, by Milton Stern and A. L. Geary

Oxygen Concentration Cell as a Factor in the Localized Corrosion of Metals, by Wilson Lynes

Thursday, October 4, Electrochemistry of Corrosion

The Mechanisms of Aqueous Corrosion of Aluminum at 100 C, by K. M. Carlsen

Contribution to the Theory of Stress Corrosion in Duralumin Alloys, by W. H. Colner and H. T. Francis

Galvanic Corrosion of the Aluminum-Lead Couple in Aqueous Pigment Extracts, by M. J. Pryor, R. J. Hogan and F. B. Patten

Thermogalvanic Potentials and Currents at Aluminum Surfaces in Industrial Water, by E. C. Pitzer

Current Efficiency of Magnesium Anodes, by E. H. Phelps

Corrosion's Technical Section is indexed annually in December.

Corrosion Inhibitive Papers Are Discussed at St. Louis

"Protective Papers Review," constituted the Second Session of the 1956 Technical Short Course in Protective Packaging and Materials Handling sponsored by the Society of Industrial Packaging and Materials Handling Engineers and presented by St. Louis University Oct. 22-25 at Kiel Auditorium, St. Louis.

The session was scheduled to include: Ferro-Pak, Marvin Chaiken, Cromwell Paper Co., Chicago.

Silicone and Quilon-Treated Papers, Thomas E. Flanagan, KVP Co., Kalamazoo, Mich.

Spot Seal, E. W. Pitt, Sherman Paper Products Co., Upper Newton Falls, Mass.

Corrosion Inhibitive Papers, Malcolm J. O'Dell, McLaurin-Angier Corp., Needham Heights, Mass.

New Nickel Oxide Standard Samples Available from NBS

Two new standard samples of nickel oxide are available from the National Bureau of Standards. Designed primarily as spectrographic standards they are useful also as chemical standards. Analyzed and certified for nine minor and trace elements, the standards are intended for checking and calibrating spectrochemical and chemical methods in the analysis of nickel, particularly cathode-grade material.

Bottled packages of 25 grams each are available from the Standard Sample Clerk, National Bureau of Standards, Washington, 25, D. C. The cost is \$4 per sample.

NBS Program to Interest Science Students Explained

A program designed to interest students in physical sciences and engineering who have demonstrated unusual scientific ability is carried on by the National Bureau of Standards. Undergraduate college students are invited to work at the bureau or one of its auxiliary locations during summer months.

Besides on-the-job-training in numerous scientific specialties, including X-ray, radio propagation and others, the Student Trainee Program includes a series of tours and lectures designed to familiarize the student with the functions of the bureau.

Radiation Effects Are Probed

The effect radiation has on materials used in nuclear reactors will be explored by a program involving small specimens at Battelle Memorial Institute, Columbus, Ohio. Corrosion is among the effects being investigated.

BOOK REVIEWS

Electrochemical Behavior of Magnesium. Equilibrium Tension-pH Diagrams for Systems Mg-H₂O, Mg CO₂, Mg H₂PO₄H₂O at 25 C. Technical Report No. 39 (In French.) By J. Van Muylder and M. Pourbaix. 29 pages, 8½ x 11¾. Centre Belge d'Etude. March, 1956. de la Corrosion, 21 rue des Drapiers, Brussels.

Combating Corrosion—A Special Symposium. 238 pages, 8½ x 11 inches, paper. April, 1956. Extension Division, College of Engineering, University of Oklahoma, Norman. Per copy, \$5. Collected papers given at the April 3-5, 1956 Corrosion Control Short Course at

University of Oklahoma cooperatively by the College of Engineering and Central Oklahoma Section, National Association of Corrosion Engineers are included. Most of the 23 papers relate to petroleum pipe lines and production. Papers cover such subjects as rectifiers, cathodic protection design, inhibitor testing, internal coating for pipelines, inspection, plastics selection, and others.

Oxidation Resistant Silicon Aluminium Steels. By E. A. Brandes. Special Report No. 2, 40 pages, 7½ x 9¾ inches, paper. August, 1956. Fulmer Research Institute, Ltd., Stoke Poges, Bucks., England. Per copy, 10/6d.

Tabulated and graphed data on the physical characteristics of steel containing up to 4 percent silicon and up to 3 percent

aluminum are reported. The steels containing 2-3 percent silicon with 0.5 to 1 percent aluminum were found to be comparable in oxidation resistance to 18-8 nickel austenitic steel at temperatures up to 900 C.

At room temperature ductility is adequate for many forming operations and is not reduced by oxidation at temperatures up to 900 C. Carbon and manganese in quantities normally encountered are without significant effect. Scaling resistance in flue gas and steam is superior to mild steel.

Resistance to corrosion in atmosphere in accelerated tests is no better than mild steel. Strength at 600 C is low.

Metallizing Bibliography. 36 pages, 8¼ x 11 inches, paper. Publication C25-1956, July 31, 1956. American Welding Society, 33 West 39th St., New York 18, N. Y. Per copy, \$1.50.

A mimeographed bibliography of 181 articles on metal spraying from 68 publications. Most titles are followed by abstracts.

Specific Resistance (Electric) of the Soil. By S. W. Boon. 58 pages, 8¼ x 11½ inches, paper. (In Dutch.) Publication 43, July, 1956. Metaalinstuut TNO, Afdeling Corrosie, Delft, Holland. Per copy, f 7.50.

Methods of measuring soil resistance are outlined and instruments discussed. Chapter 5 explains the relation between the average specific resistance of ground and its corrosivity. A 56-page book of tabulated data giving specific field data on resistance measurements of soil in Holland is included.

Cathodic Protection. By J. W. Boon. **Important Construction Factors in Fighting Corrosion.** By C. A. Lobry de Bruyn. (In Dutch.) 14 pages, 8¼ x 11½ inches, paper. Publication 42, July, 1956. Metaalinstuut TNO, Afdeling Corrosie, Delft, Holland. Price, per copy, f 2.50.

The section on cathodic protection covers principles, galvanic methods, anode and cathode reactions, criteria of full protection, secondary effects and practical experience on a pipe line. The second part covers principal materials and methods involved in using structural shapes, jointing practices, vessel design and others.

API Smog Analyzer Is Working at Los Angeles

"Silent Sam," a 1300-pound air sampling device developed at Franklin Institute, Philadelphia for research by the American Petroleum Institute has been put to work analyzing Los Angeles smog with its ultra-long-path infrared absorption cell and spectrometer. The device is located at Stanford Research Institute's laboratory in South Pasadena where several other research projects are underway on aspects of the smog problem.

Standardization Session

Ten conferences will be held January 21-25 during the Gaillard Seminar in Industrial Standardization in the Engineering Societies Building, New York City.



International Paints
were developed, each to
satisfy a new and often
unusual marine
requirement

INTERNATIONAL PAINTS

STOCKED BY

- SAN ANTONIO MACHINE & SUPPLY CO.**
Harlingen, Texas Phone: Garfield 3-5330
- SAN ANTONIO MACHINE & SUPPLY CO.**
Corpus Christi, Texas—Phone: 2-6591
- TEXAS MARINE & INDUSTRIAL SUPPLY CO.**
Houston, Texas Phone: Walnut 6-1771
- TEXAS MARINE & INDUSTRIAL SUPPLY CO.**
Galveston, Texas—Phone: 5-8311
- MARINE & PETROLEUM SUPPLY CO.**
Orange, Texas—Phone: 8-4323-8-4324
- RIO FUEL & SUPPLY CO.**
Morgan City, Louisiana Phone: 5033-3811
- ROSS-WADICK SUPPLY COMPANY**
Harvey, Louisiana Phone: Fillmore 1-3433
- MOBILE SHIP CHANDLERY CO.**
Mobile, Alabama Phone: Hemlock 2-8583

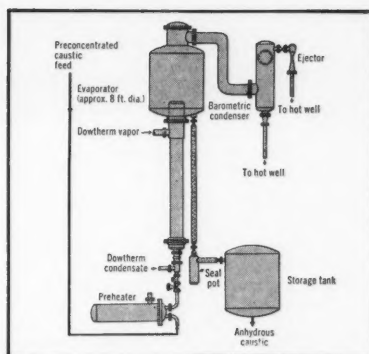
Send for a complimentary copy of our recently revised booklet "The Painting of Ships." It is an outline of the latest approved practices in all marine maintenance.



International Paint Company, Inc.

Main Office: 21 West Street, New York 6, N. Y. Southern District Office: 628 Pleasant Street, New Orleans 15, La.—Phone: TWInbrook 1-4435
Union, Union Co., N. J., U. S. A. • S. San Francisco, Cal., U. S. A.





Schematic drawing of Swenson Evaporators. In these units, jacketing is eliminated: thermal insulation prevents freeze-up. Low-carbon nickel tubes, tube sheets, shells and piping keep corrosion low and prevent product contamination.

You don't have to "shade" solid NaOH made in Nickel

What's more...

- With good control of chlorate, metal pick-up does not exceed 1 or 2 parts per million.
- Original equipment costs only 1/5 as much as a batch-finishing, direct-fired, iron pot installation of equal capacity.
- A set of nickel tubes can finish some 17,000 tons of caustic and costs less than 1/2 as much to replace as pots.

Modern practice is to produce 99.5% solid NaOH continuously in Dowtherm®-heated evaporators with contact surfaces of corrosion-resisting low carbon Nickel. The chlorate-free feed is either 50 or 73% NaOH.

"Shading" pots have never been needed. Caustic is packed directly from the nickel storage tanks.

*Trademark of Dow Chemical Company

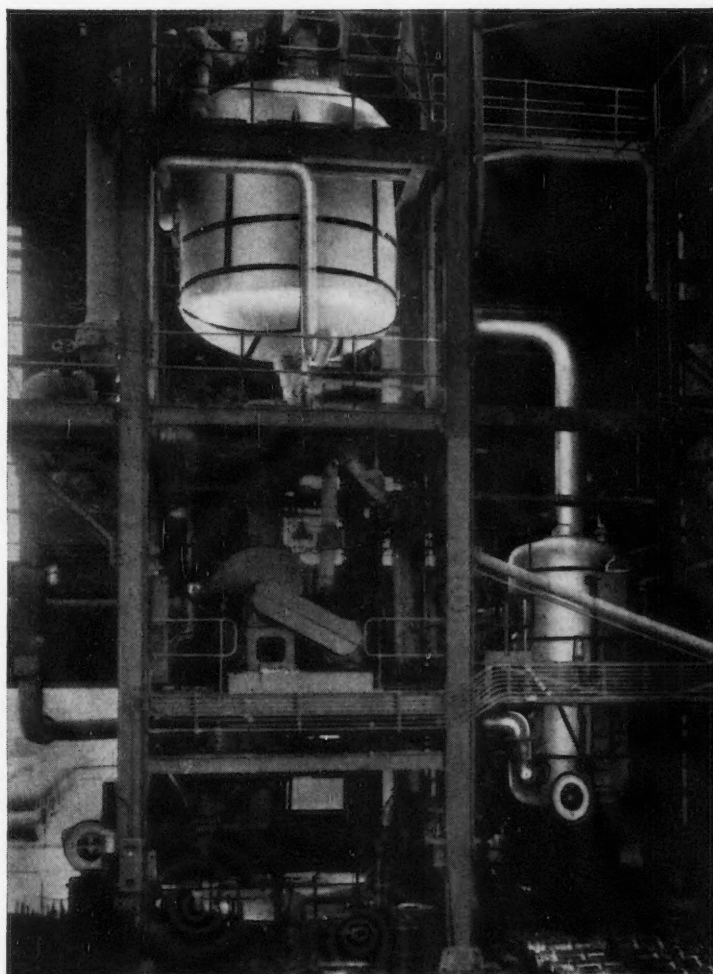
For further information on continuous caustic finishing units, write Swenson Evaporator Company, Harvey, Illinois. For assistance with caustic corrosion problems, contact Inco's Corrosion Engineering Section.

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.



Nickel

... for purity



Continuous finishing of anhydrous caustic soda in Swenson Evaporators has proved highly economical. This is

one of the latest units, installed at Murgatroyd's Salt and Chemical Co., Ltd., England.

This information of continuous caustic finishing is published through the courtesy of the Swenson Evaporator Company and Dr. W. L. Badger, originator of the process and designer of the unit.

Equipment Services

Teflon and Rulon tape in widths from ¼-inch to 3 inches is being skived from molded plugs by the Dixon Corp., Bristol, R. I. By a new method it developed, the company can bond the tapes to surfaces with adhesives.

Activated Charcoal filtration equipment available from Pur Air Div., Barney-Cheney Co., Columbus, Ohio is described in a new publication available from the company. A bibliography of studies on the use of activated charcoal is included.

Small Piping in sizes from ½-inch up intended for welded instead of screwed joints is available from Tube Turns, Louisville, Ky. The Schedule 40 and 80 pipe has more wall thickness when welded than when joined by threaded connections. Welded joints are said to be faster than threaded joints to complete.

Photodiodes, new light sensitive transistors developed by Westinghouse Research Laboratories are said to be 10,000 times more sensitive to light than the standard "electric eye" and can control as much current as 100 standard photoelectric cells. With a 1½ volt dry cell as a power source a photodiode as small as a dime can operate a standard relay without amplification.

COKE BREEZE

Backfill for Anodes

Ideally suited for use with anodes. Has a high carbon content and comes in sizes of ⅜-inch x 0 to ¾ x ⅞-inch. In bulk or sacks. Prices on other sizes on request.

**National Carbon
Anodes
Magnesium Anodes
Good-All
Rectifiers**

Wholesale Coke Company

PHONE BIRMINGHAM, ALA.,
GARDENDALE EXT. 3-2424

**P. O. Box 94
MT. OLIVE, ALABAMA**

NEW PRODUCTS

Materials Literature

Titanium Sponge at the rate of 10 million pounds a year will be produced by a new U. S. Industrial Chemical Co. plant located near Ashtabula, Ohio.

pH Meter, pocket sized, can be used to accurately measure acidity or alkalinity and is available from Scientific Instruments Division, Beckman Instruments, Inc., 2500 Fullerton Rd., Fullerton, Cal. The battery operated instrument has a range from 2 to 12 pH and a memory dial for standardizing.

Hughes Aircraft has been given an order for one million diodes by Logistics Research, Inc. for use in Alwac computers and other data processing equipment.

Molybdenum Chemicals' sources and applications are described in a 4-page bulletin available from Climax Molybdenum Co., Dept. L, 500 Fifth Ave., New York 36, N. Y. The bulletin is designated Ch-27. Over 50 developmental molybdenum chemicals currently manufactured for research purposes are listed.

Carboline Co., St. Louis has named March Corp., 18101 James Couzens Highway, Detroit 35, Mich. as sales representatives in Michigan and Lucas County, Ohio. Among the associates in the firm are Eugene V. Ivanso, recently named secretary-treasurer of North Central Region NACE.

Tygon Flexible Plastic Tubing, Bulletin T-97 available from Ralph Bjorgen, Plastics and Synthetics Div., U. S. Stoneware Co., Akron 9, Ohio covers Tygon formulations as to physical properties, applications and limitations. Included are data on laboratory tubing, food and beverage host, hospital and surgical tubing, semi-rigid, general utility chemical hose; flexible chemical hose, flexible low temperature tubing, vacuum tubing, outer braid reinforced tubing, cleaning methods, special formulations and fittings.

Alco Products Beaumont, Texas expansion project completed at \$2 millions will increase production of heat exchangers and oilfield equipment.

An Experimental Reactor now being assembled in its Lynchburg, Va. critical experiment laboratory by Babcock & Wilcox Co. will use enriched Uranium-235 as fuel. Fuel elements will contain uranium-diffused plastic tape sandwiched between thorium "converter" plates, the first time thorium has been used in a reactor, the company says.

High Purity Rare Earth oxides imported from Johnson, Matthey & Co., London are available in the United States from Jarrell-Ash Co., 26 Farwell St., Newtonville, Mass. Various grades from spectrographically certified highest available purity (up to 99.998 percent) are available. In addition to oxides, rare earth salts are available also. Rare earths include lutetium, gadolinium, samarium, thulium, dysprosium and europium.

Metaz, a new paint reported to have superior resistance to many corrosives is available from The Sealube Co., Wakefield, Mass. The material has an epoxy base.

Ceramics with speedy response to humidity, measured with a resulting response to 90 percent of the full change in relative humidity in under 30 seconds have been developed by Horizons Inc., 2905 East 79th St., Cleveland 4, Ohio.

Columbium and Tantalum oxides up to 99.5 percent purity have been developed recently by Kennametal Inc., Latrobe, Pa. Technical grade oxides will be available for industrial research and commercial purposes.

130 kv Portable X-ray with a tube head weighing only 50 pounds and capable of penetrating 1½ inches of steel is available from Holger-Andreasen, Inc., 703 Market St., San Francisco, Cal.

A Polyvinyl Acetate mixture called "Tite-Crete" is recommended for producing bonds to old concrete surfaces by surface Engineering Co., Inc., Wichita, Kans. Bonds as much as 10 times stronger than those available with plain cement mortars are claimed.

Technocheck-PVC, a polyvinyl chloride check valve designed to handle salt solutions, fuels, oils, acids, alkalies, food products and other materials is available from Techno Corp., 16 West 5 St., Erie, Pa.

Industrial Reactor Laboratories, Inc. will build and operate a privately owned nuclear reactor for industrial research at Plainsboro, N. J. The organization was formed by 10 of America's large corporations.

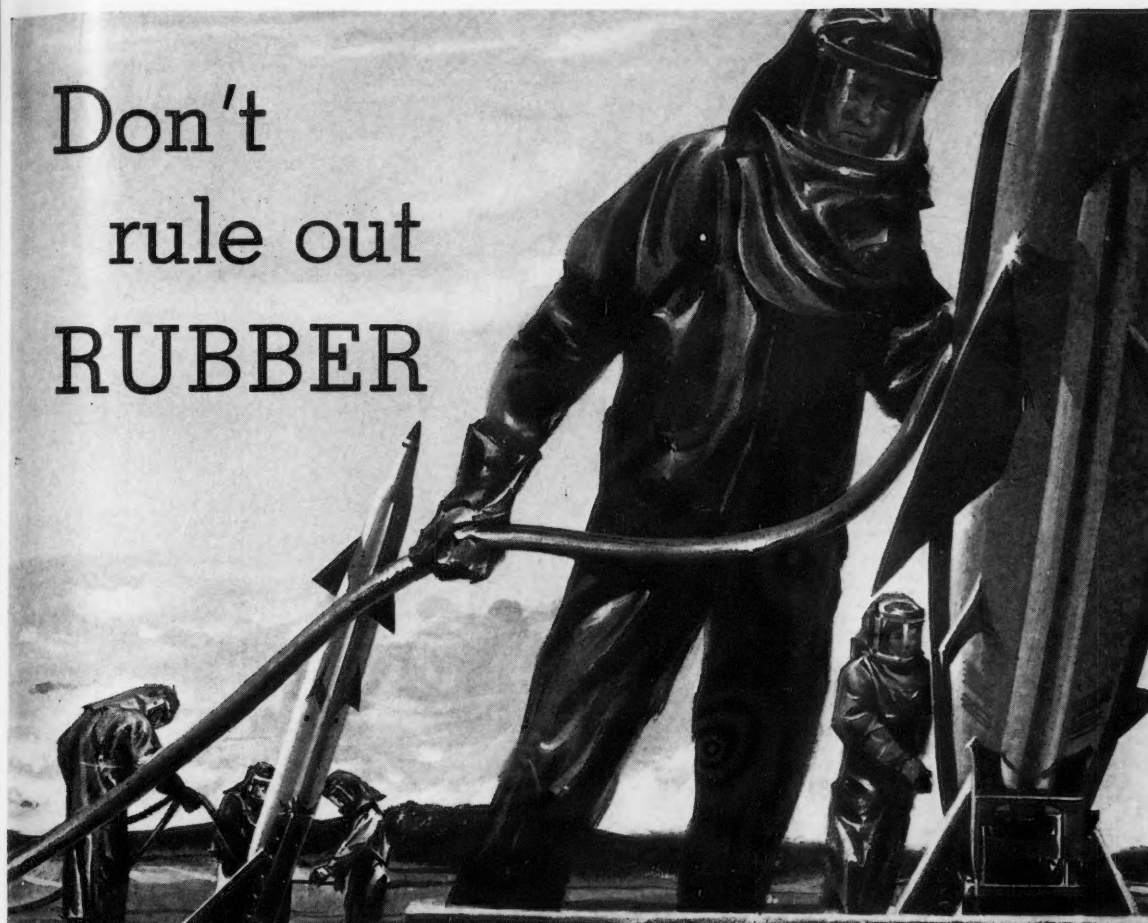
Indium, when used as a component of solders containing tin, lead and silver produces a harder and stronger solder that is more resistant to corrosion, according to Alpha Metals, Inc., 56 Water St., Jersey City, N. J. The new alloy is especially resistant to lye and other alkalies.

T-65 Temper is the designation given to aluminum alloy hand forgings with a low level of internal stress. A new tempering process developed by Aluminum Company of America is credited. The method may be adapted to other forgings.

Corrosion Rates of metals exposed in a working system can be continuously measured and recorded through use of the Corrosometer, a device developed by Crest Instrument Co., 11808 South Bloomfield Ave., Santa Fe Springs, Cal. The device, by measuring the electrical resistance of a material specimen exposed in the corrodent, permits readings at any convenient interval, continuous recording or remote readings. It is not necessary to remove the probe to make readings. Temperature changes are negated by simultaneous exposure of a

(Continued on Page 96)

Don't rule out RUBBER



Transfer Hose of KEL-F Elastomer handles red fuming nitric acid over long periods of time without deteriorating. Protective Clothing of elastomer-coated fabric shields workers from corrosive materials.

KEL-F® Fluorocarbon Elastomers are doing jobs that rubber never did before!

Rubber is perhaps the most useful and versatile non-metallic material used by industry today. Its resilience and resistance to abrasion and breakdown make it an important tool in industrial techniques and plant equipment.

Yet in many applications—where the mechanical properties of rubber are vitally needed—extremely high-temperature and corrosive operating conditions rule out its use.

The development of KEL-F Fluorocarbon Elastomer fills a long felt need. Here is a high strength rubber that can operate effectively under conditions that swell, stretch and melt ordinary rubber.

Today, KEL-F Elastomer can be considered for those jobs once thought "impossible" for rubber. Just check its outstanding properties:

- Extreme resistance to acids, ozone, and other oxidants
- Thermal stability to 400°F.
- High resistance to solvents, fuels and lubricants
- Low moisture absorption
- Good dielectric properties
- Non-flammability

KEL-F Elastomers have convincingly demonstrated their value in a variety of industrial roles: As *sealants* for corrosive liquids, abrasion and corrosion resistant *pump impellers* . . . heat and chemical resistant *hose, tubing, diaphragms, gaskets* . . . *transmission, brake and aircraft seals* . . . corrosion and flame resistant *protective clothing* . . . electrical and shock *insulation*.

This new elastomer is a result of Kellogg's comprehensive research in fluorocarbon chemistry. Its performance characteristics are well established in the chemical, electrical and equipment fields. If your work involves rubber at any point, then KEL-F Elastomer warrants investigation.

Our Technical Staff is prepared to work with you in adapting KEL-F Elastomer to your needs. For further information, write: The M. W. Kellogg Company, Chemical Manufacturing Division, P. O. Box 469, Jersey City 3, N. J.

THE M. W. KELLOGG COMPANY

Subsidiary of Pullman Incorporated



®KEL-F is the registered trademark of
The M. W. Kellogg Company for its fluorocarbon products.

NEW PRODUCTS

(Continued from Page 94)

protected specimen and because corrosion products do not influence the results direct readings are given in mils of metal lost. The device is described fully in a 10-page bulletin available from the company. Reports on numerous test applications in a variety of plants are available also.

Transistorized soil resistivity meters developed by Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Cal. provide AC for measurement without polarization. The completely electronic circuit is reported to be exceptionally reliable under field conditions.

Drygalv cold galvanizing compound, which can be applied like paint with brush or spray gun has 95 percent zinc in the dried coating. American Solder and Flux Co., 19th and Willard St., Philadelphia, Pa. says the material dries to touch in 15 to 30 minutes and can be used at temperatures up to 392 F intermittently.

Aquathene and **Gencathene** are names given to two cables developed by General Cable Corp., 420 Lexington Ave., New York 17, N. Y. specifically for use in cathodic protection systems. Aquathene has a neoprene jacket while Gencathene has a polyethylene jacket. Both are available with copper or aluminum conductors.

Chemical Linings, Inc. has purchased a

building at 156 Stone St., Watertown, N. Y.

Polyethylene is used to make a two-piece cover designed to fit over pressure splices on electrical cable. The cover is elastic at the port through which the wire passes and will cover No. 8 stranded aluminum or copper wire with either polyvinyl or polyethylene jacket and also up to No. Two 7-strand wire with TW or Neoprene cover. It is said by manufacturer, Plastic Engineering & Sales Corp., P. O. Box 1037, Fort Worth to work over Kearney, Burndy, T & B and other compression splicing sleeves, eliminating costly hand taping.

22-inch Lateral pipe connecting the American Louisiana Co. main line in Defiance, Ohio with the Michigan-Wisconsin pipeline near Bridgman, Mich. has been power wrapped with Polyken polyethylene tape. The 122-mile line is the longest large diameter pipe line known to have been protected with tape in this country.

Chemical Hybridization was used to create a new heat resistant rubber which withstands swelling by aircraft fuels and oils. Silastic LS-53, Dow Corning's new fluorosilicone rubber is a molecular hybrid of its two obvious constituents. It is said to have the ease of fabrication of silicone rubbers which the solvent resistant of the fluorocarbons.

Super Pressure tubing in AISI Types 304, 316, 321, 347 and 4130 rated for service at pressures up to 100,000 psi is available from Superior Tube Co., 1417 Germantown Ave., Norristown, Pa. Data Memorandum No. 22 gives more information.

Steel Structures Painting Bulletin, a free quarterly publication is available to persons interested in its subject matter. Copies may be obtained by writing to Joseph Bigos, Editor; Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh 15, Pa.

TC Primecoat, a priming solution developed by Tapecoat Co., 1523 Lyons St., Evanston, Ill. gives users a primer compatible with the coal tar pitch base used in Tapecoat protective materials.

Unplasticized PVC is the material for a slip type pipe expansion joint available from Tube Turns Plastics, Inc., Louisville, Ky. Expansion of 3/4 inches is allowed by 1, 2 and 3-inch sizes available. Smaller piping diameters may be used with reducing bushings. The joint is designed for use with PVC piping subject to thermal cycles.

Ansul PS-30 extinguisher dispenses 30 pounds of dry chemicals under impulse of carbon dioxide gas.

Refractory Materials will be examined first by Battelle ceramics specialists in a search for erosion-corrosion resistant materials for rapid fire anti-aircraft rocket nozzles. The institute is under contract with U. S. Army Ordnance's Picatinny Arsenal to do the research.

C-I Extra High, a silicone-aluminum coating is said by manufacturers Chem Industrial Co., 3784 Ridge Road, Brooklyn 9, Ohio to sustain temperatures up to 1700 degrees without blistering or burning. It also is said to have substantial resistance to corrosion and fumes.

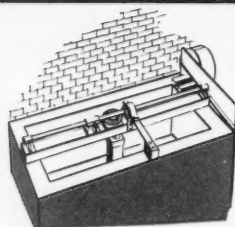
Bart Lector-Clad nickel lined pipe and fittings are described in an 8-page brochure featuring fabrication techniques and technical information. A separate section, complete with drawing shows how the clad pipe and fittings can be fabricated or repaired in the field. Free copies are available from the company at 229 Main St., Belleville 9, N. J.

Fansteel Metallurgical Corp. will build a \$6,500,000 plant at Muskogee, Okla. for production of tantalum and columbium.

Surface Preparation recommendations of Lead Industries Association, 60 East 42nd St., New York 17, N. Y. are included in Red Lead Technical Letter No. 11—Recommended Surface Preparation of Steel for Red Lead Paints.

"Welding" of pieces of graphite together provides a new technique that is expected to expand the uses for this material, according to Robert G. Breckenridge, director of the new Union Carbide and Carbon Corporation research laboratories at Arma, Ohio. National Carbon Division manages the laboratories. Dr. Breckenridge also said the largest single crystals of cadmium sulfide ever reported have been "grown" in the new laboratories. The light-sensitive material can be used in solar batteries and as a light-producing phosphorescent material. The crystals measure 3/8-inch in diameter and several inches long.

Corrosion Services Inc., P. O. Box 7343, Tulsa, Okla. has prepared a data sheet on its new air-cooled selenium rectifiers available on request.



After 5 years
TOREX® ENAMEL
 still protects alum tanks
 AT **Celanese**
 CORPORATION OF AMERICA

Alum solution in the concrete tanks at Water Filter Plant, Celanese Corporation, Belvidere, N. J., was eating through the concrete and loosening the mortar in the brick wall behind the tanks. That was back in 1951. Celanese engineers consulted Inertol Co., Inc., manufacturers of specialized coatings. Inertol's Torex Enamel was used.

For more than five years now, that first application of tile-smooth Torex has been protecting the tanks. No more concrete disintegration, leaks, downtime, repairs.

Torex Enamel is a chlorinated natural rubber-base coating, in color. It's easily cleaned, resists water-treatment chemicals. Today, send for free informative folder, "Inertol Chemical-Resistant Enamels" C-571. No obligation. Write your name, title, firm name and address in margin of this page and mail.



Inertol... a complete line of quality coatings

INERTOL CO., INC.

477 Frelinghuysen Avenue, Newark 12, N. J. • 27A South Park, San Francisco 7, California



Service



One of Cathodic Protection Service's fleet of trucks loading 1500 Duriron Anodes at the Duriron Company's plant, in Dayton, Ohio. These anodes were for delivery in Nebraska, Oklahoma, Texas and our Houston stock.

You can benefit from the complete line of cathodic protection materials available at C. P. S. Large stocks of anodes, backfill, cable and all accessories for installation are ready for you at one source, on one order for prompt shipment. Check the list below.

Duriron anodes in Houston stock, Type A, BA, B, C, D and E and Type D Durichlor.



FIRST LINE MATERIALS INCLUDE:

Duriron Anodes
Dow Magnesium Anodes
American Zinc Anodes
CPS Graphite Anodes
Good-All Rectifiers
Scotchrap Tape Coatings
Betzel Tapesters
Maloney Insulating Materials
Erica Cadweld Welding Materials
Fisher M-Scope Pipe and Cable Locators
Detectron Pipe Locators
Wahlquist Pipe Locators
CPS Graphite Anode Backfills
Homco and Barada and Page Backfills
Agra and CPS Meters
Associated Research Resistivity Meters
Rubicon Potentiometers
Pearson Holiday Detectors
Holloway Shunts
Rome Direct-Burial Cable
Ditch-Witch Trenchers

cathodic protection service

OFFICES LOCATED IN HOUSTON

P. O. Box 6387
(4601 Stanford Street)
Houston 6, Texas
CHerry 2-9857

TULSA

310 Thompson Building
Tulsa 3, Okla.
CHerry 2-9857

NEW ORLEANS

1627 Felicity
CAnal 7316

CORPUS CHRISTI

1522 So. Staples
Tulip 3-7264

DENVER

(Golden) P. O. Box 291
CRestview 9-2215

Everything in the cathodic protection field . . .
from an insulating washer to a turnkey contract installation.

MEN in the NEWS

Edgar H. Dix, Jr., assistant director of research at Aluminum Research Laboratories, Pittsburgh has been given the Albert Saver Award for his work in aluminum alloys research. **William H. Eiseman**, for more than 39 years national secretary of the American Society for Metals was chosen by society trustees to receive the ASM Gold Medal for his work in helping build the society to its present 27,000 members.

Norman A. Matthews, now a research engineer in General Electric Company's Metallurgical Products Department formerly was assistant chief metallurgist

in the materials and research and development unit of American Brake Shoe Co.

Cameron G. Harman, head of the Ceramics Dept., National Clay Pipe Research Corp., will supervise a research project seeking improvement of clay sewer pipe to be conducted by Horizons Inc. Specific aim is to produce lighter pipe without sacrificing strength.

Eldridge K. Camp, formerly with Westinghouse Research Laboratories, East Pittsburgh, Pa. is now on the engineering staff of International Business Machines Corp., Poughkeepsie, N. Y.

James W. Vicary, president Ervite Corp., Erie, has been elected to a two-

year term as president of the Porcelain Enamel Institute.

Morehead Patterson, president of American Machine and Foundry Co., New York has been elected chairman of the Nuclear Standards Board, American Standards Association at its first meeting September 18.

Howard H. Friedel is now a sales engineer with the Process Equipment Division, U. S. Stoneware Co., Akron, Ohio. He is a registered professional engineer in Ohio and is a member of AICHE and NACE.

Theodore W. Bossert has been appointed chief metallurgist of Aluminum Company of America. He will head the metallurgical division of the operating department.

Howard I. Cramer is now Director, Technical Liaison, Pennsalt Chemicals, 3 Penn Center Plaza, Philadelphia 2, Pa. to further the company's interest in foreign technological developments and the exchange of information at home and abroad.

John S. Saby has been appointed manager of the Lamp Research Laboratory of General Electric's Advanced Lamp Development Laboratory at Nela Park, Cleveland.

Robert F. Mehl, director of the metals research laboratory and Head of Metallurgical Engineering, Carnegie Institute of Technology was guest speaker October 1 at the 14th Annual Woodside Lecture of the Detroit Chapter, American Society for Metals.

Justus T. Vollbrecht, president of Energy Control Corp. New York has been elected national president of the Instrument Society of America.

Jack D. Guthrie, headquartered at Atlanta, Ga. is now on the sales and service staff of Chemical Linings, Inc.

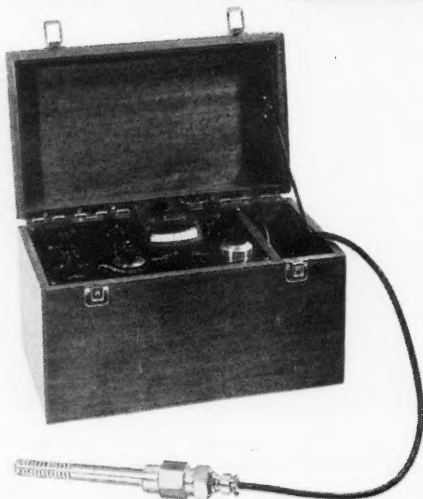
C. G. Chisholm has been appointed general sales manager of Haynes Steel Co., a Division of Union Carbide and Carbon Corp. He is a member of NACE and ACS.

William C. Greenleaf, is now manager of Metals Development for U. S. Industrial Chemicals Co. He is responsible for market development and sales of zirconium and titanium sponge to be produced by USI's two new plants in Ashtabula, Ohio.

George W. Khlor, vice-chairman of Kanawha Valley Section has been transferred to E. I. du Pont de Nemours Company's Washington Works as administrative assistant in the technical section manager's office. A graduate of the university of Illinois, he was materials coordinator for the Polychemicals Department at the company's Belle, West Virginia plant. He will continue as a consultant on materials of construction.

John F. Daley, general manager of Du Pont's Chemicals Department has been elected a director, vice-president and a member of the executive committee of the company.

NOW...for the first time measure corrosion **DIRECTLY!**



THE CORROSOMETER*

Quick, Convenient, Accurate. Now you can measure progress of corrosion at any location in your system or plant—without need for handling test coupons, taking samples or disturbing plant operations!

The Corrosometer system consists of any number of probes which remain in continuous service, and a portable meter which simply plugs into each probe to indicate extent of corrosion directly in micro-inches of metal lost.

Corrosion measured takes place on the specimen built into the probe.

Probes are available in many different constructional alloys to meet various processing requirements and systems in chemical plants, food plants, refineries—wherever corrosion is a problem. *To get the facts on how to boost corrosion control efficiency and cut your costs with the Corrosometer, write direct today for full details!*

* Trade-Mark

CREST INSTRUMENT COMPANY, 11808 South Bloomfield • Santa Fe Springs, Calif.



CORROSION ABSTRACTS

INDEX TO CORROSION ABSTRACTS

Vol. 12 November, 1956 No. 11

	Page
1. GENERAL	
1.2 Importance	99
1.5 Directories of Material	99
1.7 Organized Studies of Corrosion	100
2. TESTING	
2.1 General	100
2.3 Laboratory Methods and Tests	100
2.4 Instrumentation	104
3. CHARACTERISTIC CORROSION PHENOMENA	
3.2 Forms	104
3.4 Chemical Effects	107
3.5 Physical and Mechanical Effects	107
4. CORROSIVE ENVIRONMENTS	
4.2 Atmospheric	110
4.3 Chemicals, Inorganic	110
4.4 Chemicals, Organic	111
4.5 Soil	111
4.6 Water and Steam	111
4.7 Molten Metals and Fused Compounds	112
5. PREVENTIVE MEASURES	
5.1 General	112
5.2 Cathodic Protection	112
5.3 Metallic Coatings	113
5.4 Non-Metallic Coatings and Paints	117
5.5 Oil and Grease Coatings	119
5.7 Treatment of Medium	119
5.8 Inhibitors and Passivators	119
5.9 Surface Treatment	120
6. MATERIALS OF CONSTRUCTION	
6.3 Non-Ferrous Metals and Alloys—Heavy	122
6.4 Non-Ferrous Metals and Alloys—Light	124
6.6 Non-Metallic Materials	131
6.7 Duplex Materials	132
7. EQUIPMENT	
7.1 Engines, Bearings, and Turbines	132
7.2 Valves, Pipes and Meters	133
7.3 Pumps, Compressors Propellers and Impellers	133
7.4 Heat Exchangers	133
7.5 Containers	134
7.6 Unit Process Equipment	134
7.7 Electrical— Telephone and Radio	134
8. INDUSTRIES	
8.1 Group 1	136
8.2 Group 2	136
8.3 Group 3	136
8.4 Group 4	136
8.5 Group 5	142
8.6 Group 6	142
8.7 Group 7	142
8.8 Group 8	142
8.9 Group 9	142

1. GENERAL

1.2 Importance

1.2.2, 5.2.1, 5.4.5

Economics is a Basic Problem. M. E. PARKER. *Pipe Line Industry*, 2, No. 3, 54-56, 65 (1955) Mar.

Costs of typical coatings and various types of cathodic protection are discussed with graphs and suggestions for selling recommendations to management. 10846

1.5 Directories of Material

1.5, 6.1, 1.6

Chemical Engineering Materials. F. RUMFORD. Book, 1955, 382 pp. Chemical Publishing Co., Inc.

General mechanism of chemical attack and essential methods of material testing are shown. Range of materials available is surveyed. Specific corrosion-resistance data are given and some relative costs suggested.—INCO. 11508

1.5, 6.5

Metal Selector. *Steel*, 137, No. 15, 146 (1955) October 10.

Chart with practical information needed to select right metal for the job. Chemical compositions, SAE, AISI or commercial name, properties and typical applications are tabulated for copper wrought alloys (including copper-nickel and nickel silvers), stainless and heat-resistant steels, H-steels, titanium and titanium alloys, alloy steels, zinc die-casting alloys, ferrous castings (gray, nodu-

PHOTOPRINTS and/or MICROFILM COPIES

of Technical Articles Abstracted in CORROSION ABSTRACTS

May Be Obtained From

ENGINEERING SOCIETIES LIBRARY,
29 West 39th Street, New York 18,
N. Y.

CARNEGIE LIBRARY OF PITTSBURGH,
4400 Forbes St., Pittsburgh 13, Pa.
NEW YORK PUBLIC LIBRARY, New
York City.

U. S. DEPT. OF AGRICULTURE
LIBRARY, Office of Librarian, Wash-
ington, D. C. (Special forms must be
secured).

LIBRARY OF CONGRESS
Washington, D. C.

JOHN CRERAR LIBRARY
86 East Randolph St.,
Chicago 1, Ill.

Persons who wish to secure copies of articles when original sources are unavailable, may apply directly to any of the above for copies. Full reference information should accompany request. The National Association of Corrosion Engineers offers no warranty of any nature concerning these sources, and publishes the names for information only.

NACE will NOT accept orders for photoprint or microfilm copies of material not published by the association.

CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

Neither NACE nor the sources listed below furnish reprint copies.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.
ATS—Associated Technical Services Abstracts, Associated Technical Services, P. O. Box 271, East Orange, N. J.
AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.
BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.
BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.
BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.
CBEC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 rue des Drapiers, Brussels, Belgium.
CE—Chemical Engineering, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
EL—Electroplating, 83/85 Udney Park Road, Teddington, Middlesex, England.
EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.
IIM—Transactions. The Indian Institute of Metals, 23-B, Nottaji Subhas Road, P. O. Box 737, Calcutta, India.
INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.
IP—Institute of Petroleum. 26 Portland Place, London W.1, England.
JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguroku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.
MI—Metallurgia Italiana, Associazione Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.
MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.
NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.
NBS—National Bureau of Standards, Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.
NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.
PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.
RAD—Reynolds Aluminum Digest, 2500 South Third Street, Louisville, Kentucky.
RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.
SE—Stahl Und Eisen, Verlag Stahliesen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Post-check Koln 4110, (22a) Dusseldorf, Germany.
TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.
UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.
ZDA—Zinc Development Association. 34 Berkeley Square, London W.1.

lar and malleable irons and cast steel), aluminum casting alloys and wrought alloys, copper casting alloys and magnesium.—INCO. 11003

1.7 Organized Studies of Corrosion

1.7.1, 5.4.5

The Organization of Paint Research in the Netherlands and Some Investiga-

tions by the Paint Research Institute T.N.O. H. W. TALEN, *Official Digest, Federation Paint and Varnish Production Clubs*, 27, No. 360, 24-41 (1955) Jan.

Examples of the organization of research and the type of work carried out, including a brief report on tests on white paints. The effect of zinc oxide and other white pigments on stand oil and alkyd resins has been examined. In stand oil, zinc oxide hardens the film while other white pigments such as tita-

nium dioxide and antimony oxide give relatively soft films, fairly easily soiled and with a tendency to powder. Alkyd resin paints have much greater tensile strength than stand oil paints with a corresponding composition.—ZDA. 11016

1.7.3

What the Corrosion Engineer Can Do for Management. G. CORFIELD, *Gas*, 32, No. 1, 117-118 (1956) January.

Discusses cost and danger of corrosion and outlines various ways in which corrosion engineer in the gas industry can perform useful services. Technical and organizational problems of corrosion engineer are discussed.—INCO. 11358

R E P R I N T S OF ARTICLES PUBLISHED IN CORROSION

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Add 65c per package to the prices given below for Book Post Registry to all addresses outside the United States, Canada and Mexico. Send orders and remittances to NACE, 1061 M&M Bldg., Houston 2, Texas.

Cathodic Protection and Pipe Lines

Economic Considerations in Pipe Line Corrosion Control by L. G. Sharpe . . . 50

Mitigation of Corrosion on City Gas Distribution Systems by A. D. Simpson, Jr. . . 50

Final Report—Effect of Exposure to Soils on the properties of Asbestos-Cement Pipe by Melvin Romanoff and Irving A. Denison . . . 50

Application of Cathodic Protection to 48 Well Casings and Associated Production Facilities at Waskom Field by G. L. Doremus, W. W. Mach and J. J. Lawnick . . . 50

Corrosion Control Practices for Pipe Type Cables on the Detroit Edison System by W. A. Sinclair . . . 50

Economics

The Cost of Corrosion to the United States by H. H. Uhlig . . . 50

Relation of Corrosion to Business Costs by Aaron Wachter . . . 50

Inhibitors

Prevention of Corrosion in Cooling Water by R. C. Ulmer and J. W. Wood . . . 50

Dicyclohexylammonium Nitrite, a Volatile Corrosion Inhibitor for Corrosion Preventive Packaging by A. Wachter, T. Skei and N. Stillman . . . 50

Effect of Purification of Commercial Sulfonates on the Corrosion Stain Property by Harry C. Muffley, Van Hong and David Bootzin . . . 50

Metallurgical Factors

Resistance of Aluminum Alloys to Weathering by C. J. Walton, D. O. Sprawls and J. A. Nock, Jr., and Resistance of Aluminum Alloys to Contaminated Atmospheres by W. W. Binger, R. H. Wagner and R. H. Brown . . . 50

Laboratory Studies on the Pitting of Aluminum in Aggressive Waters by T. W. Wright and Hugh P. Godard . . . 50

The Corrosion Behavior of Aluminum by Hugh P. Godard . . . 50

Salt Spray Testing Bibliography by Lorraine Voight . . . 50

Air Injection for Prevention of Hydrogen Penetration of Steel by W. A. Bonner and H. D. Burnham . . . 50

Oxide Films on Stainless Steels by Thor N. Rhodin . . . 50

Stress Corrosion Cracking of Hardenable Stainless Steels by F. K. Bloom . . . 50

Miscellaneous

Causes of Corrosion in Airplanes and Methods of Prevention by N. H. Simpson . . . 50

Corrosion Control by Magic—It's Wonderful by H. H. Uhlig . . . 50

Why Metals Corrode by H. H. Uhlig . . . 50

Methods of Preventing Corrosion in Sewerage Systems by Ervin Spindel . . . 50

Positive Polarity Grounding of Direct Current Supply Requirements in Mining Traction Systems by Sidney A. Gibson . . . 50

Corrosion Studies on a Model Rotary Air Preheater by G. G. Thurlow . . . 50

Effects of Contamination by Vanadium and Sodium Compounds on the Air-Corrosion of Stainless Steel by G. W. Cunningham and Anton de S. Brasunas . . . 50

A Simple Graphical Method for Checking the Adequacy of Stress Corrosion Specimen Dimensions Against Stress Concentrations by Robert H. Hay . . . 50

Paints and Coatings

Gasoline Resistant Tank Coatings by W. W. Cranmer . . . 50

Organization and Administration of a Plant Painting Program by W. E. Chandler and C. W. Sisler . . . 50

Selection and Application of Coatings in the Pulp and Paper Industry by Raymond B. Seymour . . . 50

Petroleum Production & Storage

Corrosion in Condensate and in High Pressure Sweet Oil Wells by R. C. Buchan . . . 50

Symposium on Internal Corrosion of Tankers. Part 3—Corrosion Control in Practice by A. B. Kurz . . . 50

Corrosion Control in Gas Lift Wells, II Evaluation of Inhibitors. By D. A. Shock and J. D. Sudbury . . . 50

Internal Corrosion in Domestic Fuel Oil Tanks by R. Wieland and R. S. Treseder . . . 50

Plastic Materials of Construction

Oilfield Structural Plastics Test Data Are Given . . . 50

Service Reports on Oilfield Plastic Pipe . . . 50

2. TESTING

2.1 General

2.1.1

Atmospheric Corrodibility Index. E. E. WHITE, *Chemistry & Industry*, No. 30, 952 (1955) July 23.

The Brit. Iron and Steel Res. Assoc. Atmospheric Corrosion Subcommittee defines an atmospheric corrodibility index of iron or steel as the ratio of weight loss of a sample to that of a reference specimen of copper-bearing mild steel of the same dimensions and identical exposure. Conditions and limitations are defined. 11028

2.1.1

Nomograph for Corrosion Rate Calculations: A Technical Note. HENRY K. BASS, JR. and ROBERT V. ANDREWS, *Corrosion*, 12, No. 1, 4t-5t (1956) Jan.

A nomograph which facilitates the determination of corrosion rate in mils per year is described. A typical problem involving calculation of corrosion rate is worked out on the accompanying nomograph. 11354

2.1.1, 2.2.2

Atmospheric Corrodibility Index. F. L. LAQUE (Inco), *Chemistry & Industry*, No. 46, 1486 (1955) Nov. 12.

Letter to the editor discussing a formula suggested by E. E. White for calculating an atmospheric corrodibility index for any steel in terms of its performance relative to a reference copper-bearing steel. To illustrate possible index variations associated with different exposure periods, results obtained in tests undertaken under the writer's direction are given. Perhaps the best way to describe ability of a steel to resist atmospheric corrosion would be to publish weight-loss vs. time-curves for the steel and a standard copper steel exposed in the same way in the same place and for the same time, thus permitting anyone to calculate his own corrodibility index in terms of weight loss after any selected period or in terms of time required to remove a certain thickness (weight) of metal by corrosion. Ideally, weight-loss data should be supplemented by similar data on progress of pitting with time.—INCO. 11447

2.3 Laboratory Methods and Tests

2.3.2, 3.5.9, 4.2.3

The Evaluation of Corrosion Resistance for Gas-Turbine-Blade Materials. W. E. YOUNG, A. E. HERSHEY and C. E. HUSSEY, Paper before Am. Soc. Mech. Engrs., Ann. Mtg., Gas Turbine Power

side give
y soiled
Alkyd
tensile
with a cor-
11016

Can Do
Gas, 32,

f corro-
n which
industry
technical
corrosion
11358

ex. E. E.
No. 30,

Assoc.
mittee
ility in-
ratio of
of a ref-
ing mild
id iden-
limita-
11028

te Cal-
ENRY K.
vs. Cor-
an.
ne deter-
mils per
lem in-
rate is
g nom-
11354

ex. F. L.
try, No.

y a for-
ite for
dibility
its per-
copper-
ible in-
different
ined in
er's di-
est way
o resist
to pub-
for the
eel ex-
ne place
mitting
dibility
ter any
ime re-
ckness
Ideally,
mented
pitting
11447

nd

Resist-
aterials
n C. E.
Mech.
Power

and Fuels Div., N. Y., November 28-December 3, 1954. *Trans. ASME*, 77, No. 7, 985-994 (1955) Oct.

Short-time tests with corrosion measured by increase in surface roughness in conjunction with microash-fusion determinations are rapid and convenient means of assessing potential corrosive properties of residual fuel oils as substantiated by operating experience with a gas-turbine locomotive and by long-time laboratory tests with combustion rigs operating at atmospheric pressure. Tests were made on 25-20 stainless, Stellites 23 and 31 and Inconel X. Vanadium pentoxide and sodium sulfate are the most prevalent sources of corrosion. Catastrophic corrosion occurs with vanadium pentoxide at 1200-1300F and with sodium sulfate at 1600-1700F. Inconel has best resistance to vanadium attack but poor resistance to sodium sulfate. Magnesium oxide in suitable proportions reduces corrosion due to both these agents. Tables, graphs, 10 references.—INCO. 11055

23.2, 6.2.5

Problem of Accelerating the Tendency of Austenitic Stainless Steels to Intercrystalline Corrosion. (In Russian.) I. L. ROZENFELD, Z. A. VRUTSEVICH, E. I. TIKOVA AND M. V. BEGANOV. *Zavodskaja Laboratoriia*, 21, No. 8, 934-936 (1955) Aug.

Comparison of sulfuric acid plus copper sulfate and other combinations in one- and two-day tests. Micrographs. 6 references.—BTR. 10974

23.2, 6.2.5

On Testing Methods for the Intergranular Corrosion Susceptibility of 18-8 Stainless Steels. (In Japanese.) HIDEO TOGANO. *Reports Government Chemical Industrial Research Institute*, Tokyo, 50, No. 8, 267-278 (1955) Aug.

Author studies detecting ability of 5% sulfuric, 65% nitric and nitric-hydrofluoric acid tests and proposes improved measures. Tables, graphs, micrographs, diagrams. 10 references.—BTR. 10994

23.2, 6.2.5

Methods of Testing Stainless Steels for Their Tendency to Intercrystalline Corrosion. (In Russian.) G. L. SHVARTS, I. I. KAZENNOV AND E. I. ASTROV. *Zavodskaja Laboratoriia*, 21, No. 8, 922-930 (1955) August.

To show the inadequacies of accepted methods, tests were made on welded joints in sulfuric and nitric acids and other corrosive media. Resistance to corrosion is demonstrated on steels subjected to boiling acid media. Diagrams, tables, micrographs.—BTR. 11004

23.2, 6.2.5

Methods of Testing Stainless Steels for Intercrystalline Corrosion. (In Russian.) A. V. SHREIDER. *Zavodskaja Laboratoriia*, 21, No. 8, 937-940 (1955) Aug.

Effect of ratio of titanium to carbon; anode etching in acids. Graphs. 10 references.—BTR. 11010

23.2, 2.1.2, 3.8.2

Electrochemical and Chemical Factors in Wet Corrosion. (In French.) B. LE BOUCHER. *Métalurgie, corrosion-industries*, 30, No. 361, 324-339 (1955) Sept.

Electrochemical nature of corrosion. Accelerated tests of corrosion. Conditions of tests; data evaluation. Graphs, diagrams. 10 references.—BTR. 11440

23.7, 3.5.3

On the Mechanism of Cavitation Damage. M. S. PLESSET AND A. T. ELLIS. Paper before Am. Soc. Mech. Engrs., Ann. Mtg., N. Y., Nov. 28-Dec. 3, 1954. *Trans. ASME*, 77, No. 7, 1055-1064; disc., 1064 (1955) October.

Describes a new method for producing cavitation damage in which test specimen has no mechanical accelerations applied to it in contrast to conventional magnetostriction device. Alternating pressures are generated in water over specimen by exciting a resonance in the water cavity. Photomicrographic examination and X-ray diffraction patterns of ordinary polycrystalline specimens (including nickel, 18-8, Colmonoy, Stellite, brass and titanium) and of zinc monocrystals show that plastic deformation occurs. This plastic deformation sets in immediately in nickel, brass and titanium.

Studies carried out in liquid toluene and in a helium atmosphere show that chemical effects can be of secondary significance. Photomicrographs, diffraction patterns.—INCO. 10959

23.7, 5.4.5

Testing the Porosity of Protective Coatings. K. PANHAUSER. *Ind.-Lack.-Betrieb*, 23, No. 4, 76 (1955).

Methods of detecting pores in paint films on metal substrates are briefly reviewed, with particular reference to an electrical method for steel structures.—RPI. 10924

23.9, 6.2.1

Colour Metallography of Ferrous Alloys. (In Italian.) A. SCORTECCI AND C. DURAND. *Metallurgia Italiana*, 47, No. 7, 305-308 (1955) July.

Gives 29 color photomicrographs. Ma-



E. R. P. CATHODIC PROTECTION ...

*individually designed for
each application*

An effective installation that operates at the lowest cost per year requires experienced engineering evaluation of site and environmental conditions. The Electro Rust-Proofing Engineering Division makes available to you the cumulative experience gained in designing more than 10,000 cathodic protection systems.

Electro Rust-Proofing can furnish any one, or all, of the following services to help you provide proper cathodic protection for each of your jobs:

- Corrosion surveys and recommendations
- Design based on engineering experience
- Cathodic protection equipment and installation
- Service to assure proper operating results

For additional information write today.



ELECTRO RUST-PROOFING CORP.

A SUBSIDIARY OF WALLACE & TIERNAN INC.

30 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CABLE: ELECTRO, NEWARK, N. J.

terials examined include carbon-steel, 18:8 stainless, 12% manganese-steel and various cast irons (including S. G. type).—BNF. 10968

2.3.6

Metallurgical Aspects of Microscopy. B. W. MOTT. *Research*, 8, No. 8, 307-313 (1955) August.

A review of recent progress (42 references): Phase contrast microscopy, oblique and opaque stop illumination, interferometry, polarized light, ultraviolet light, examination of hot metal surfaces, miscellaneous.—BNF. 10900

2.3.7

Evaluating Physical Properties of Coatings. J. I. RICHARDSON. *Amercoat Corp. Chem. Eng.*, 62, No. 11, 242, 244, 248 (1955) Nov.

Discusses tests for determining permeability, thickness, adhesion, flexibility, impact resistance and abrasion resistance of coating as means of evaluating its effectiveness as a barrier between environment and underlying surface.—INCO. 10950

2.3.8

High Pressure-High Temperature Unit for Liquid-Solid Reactions. W. H. DRESHER, T. M. KANEKO, W. M. FASSELL, JR. AND M. E. WADSWORTH. *Ind. & Eng. Chem.*, 47, No. 9, 1681-1685 (1955) Sept.

Lab-scale pilot plant for studying liquid-solid reactions has automatic temperature and pressure regulation and indication, allows sampling during operation and has unique feature of an agitator drive assembly completely contained within separately pressurized chamber in autoclave. All parts in contact with solution or its vapor are fabricated from Type 316. To protect body of autoclave from corrosive action of various systems, series of liners of silver, Inconel, nickel, Monel, Nichrome and Type 316 was made. Autoclave consists of three parts. Reaction compartment is a standard 2-liter Parr autoclave of Type 316. Intermediate compartment, which provides space for entry of all accessories, is of 3-inch schedule 80 Type 316 and is

fastened to head of autoclave by six Type 316 cap screws. Twelve Type 316 cap screws hold motor compartment, stainless steel pressure diaphragm and intermediate compartment together. Gas is admitted through stainless needle valve. Thermocouple well is Type 316 tubing. Sampling device was constructed from valve stem and bonnet of Type 316 needle valve. Capillary tube, collection bomb and safety blowout disk are all of Type 316 as is agitator drive shaft. Alnico permanent magnet was substituted for motor armature. Temperature measuring device is an iron-Constantan thermocouple with a Type 316 protection sheath. Diagrams.—INCO. 10932

2.3.4, 2.3.9

A Contribution Relating to the Execution of Corrosion Tests. (In German.) LUIGI RICCOBONI, PAOLO PAPOFF AND IDA MARIA VEZZOSI. *Werkstoffe und Korrosion*, 6, No. 12, 569-571 (1955) Dec.

Description of test apparatus for determining corrosion-time relationships of a specimen in a constant amount of electrolyte and in absence of a gas phase. A polarographic control is used. Diagram. 16 references.—BTR. 11494

2.3.5

Application of Backside Luggin Capillaries in the Measurement of Nonuniform Polarization. M. EISENBERG, C. W. TOBIAS AND C. R. WILKE. *J. Electrochem. Soc.*, 102, 415-420 (1955) July.

The backside capillary is demonstrated to be a suitable tool in the measurement of local values of polarization, particularly when interference with hydrodynamic conditions at the solution electrolyte interface needs to be avoided. The design and performance of several capillaries are described. A simple capillary machined of Teflon plastic is shown to yield satisfactory accuracy in polarization measurements. When the current distribution is nonuniform due to geometry or convection, cathodic polarization is shown to depend on the position of the capillary opening in the cathodes. 11481

2.3.5

Practical Limits of Electrical Measuring Technique Determined by the Metallic Materials. Part I. Fundamentals of the Measuring Technique. (In German.) E. ENNULAT. *Metall*, 9, No. 9/10, 382-386 (1955) May.

Principles and accuracy of current and voltage measuring apparatus. DC current and voltage: potentiometer and moving coil methods. AC and DC current; hot wire galvanometer, iron-free dynamometer and moving iron galvanometer.—BNF. 11474

2.3.6

Improvement in Replica Techniques for Electron Microscopy. (In French.) A. FUKAMI. *Metaux, Corrosion-Industries*, 30, No. 357, 220-228 (1955) May.

Improvements and resolution of standard replica techniques and detailed description of a positive replica using the impression of specimen on a cellulose film.—BNF. 11412

2.3.7, 2.1.1

Accelerated Fatigue Testing. C. J. GUARE AND L. S. LAZAR. *ASTM Bull.*, No. 208, 21 (1955) Sept.

Discusses Prot's method of progressive loading for accelerated fatigue testing [*Rev. Met.*, 45, 481-489 (1948) Dec.] Some corrections to the mathematical calculations are suggested.—BNF. 11464

2.3.7, 3.5.6, 6.3.3

Method of Determining the Diffusivity of Gas in Metal: Oxygen in Chromium. D. CAPLAN AND A. A. BURR. *J. Metals* (Trans. AIME), 7, No. 9, Section 2, 1052 (1955) September.

Two pieces of chromium sheet of different thicknesses are packed in mixed powders of chromium and chromic oxide, sealed in evacuated metal capsules of austenitic stainless steel (for temperatures up to 1350°C) or molybdenum (for higher temperature) and heated to a specific temperature for a time sufficient to saturate with oxygen the thinner but not the thicker specimen. After cooling, both samples are analyzed for oxygen by the vacuum-fusion technique. Then, assuming the surface of the specimens is kept saturated with oxygen throughout the experiment, the diffusivity can be calculated by application of the appropriate solution to Fick's second law. By performing the experiment at two temperatures and plotting the diffusion coefficient D against $1/T$, D for any temperature is established; the activation energy can be calculated from the slope of the curve. Thus, once D is known as a function of temperature, it is a simple matter to estimate the correct reaction time for experiments with single specimens at other temperatures. By this method, the solubility of oxygen in chromium has been found to be ~0.03 percent at 1350°C and less at lower temperatures. The method is not only useful for determining reaction times to equilibrium, but also for determining D in systems for which the conventional techniques are experimentally difficult or impossible.—MA. 11417

2.3.9

New Developments in Polarography and Voltammetry. P. DELAHAY. *Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics* (Poitiers, 1954), 1955, 509-532; disc. 533-536.

Developments during the last decade are reviewed. The emphasis is placed on fundamental ideas rather than on

Mayes Bros. specializes in coating and wrapping only

WITH NOTHING TO SELL BUT SERVICE!

For the past 28 years we have specialized in but ONE service—quality coating and wrapping of pipe. We can do a better job for you specializing in one service than dabbling in several.

THAT'S WHY we're not in the:

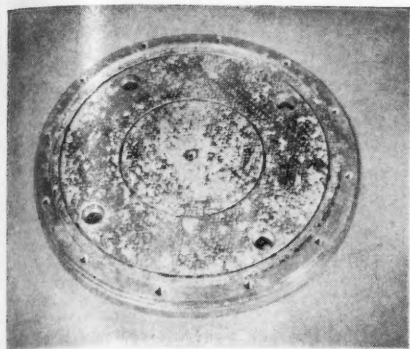
- Trucking Business — we leave that to companies who specialize in transportation.
- Supply Business — it requires expensive inventories, constant attention and merchandising skills.
- Thread Business — it requires specialized equipment and specialized experience.
- Stevedoring Business — we leave that to longshoremen with their know-how.

Nobody does his best when he's trying to wear several different hats. When you need quality coating and wrapping—let Mayes Bros. specialize men, methods and machinery Put Permanence in the pipe you lay.

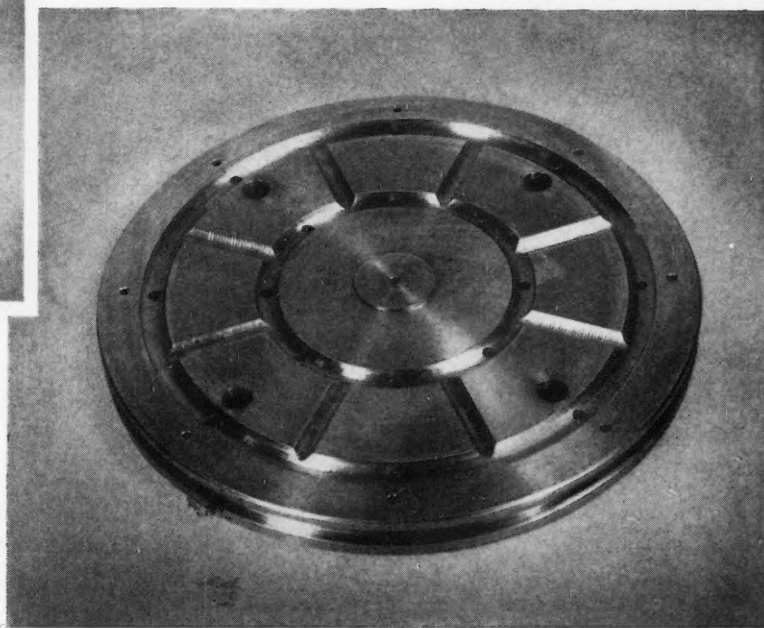
1150
McCart
Drive

MAYES BROS.
HOUSTON, TEXAS

Tel.
ORchard
2-7566



CORROSION-RESISTANT COMPONENT of filter press unit is severely pitted from chloride ion attack of calcium hypochlorite in just 2 weeks.



TITANIUM COMPONENT of filter press is clean, uncorroded after 7 months' exposure to calcium hypochlorite solution.

Titanium Filter Press Resists Attack of Corrosive Bleach

Pennsalt titanium unit shows no sign of chloride pitting after seven months' use

At Pennsylvania Salt Manufacturing Co., titanium is used for contact parts of the filter press employed in making solid cakes of calcium hypochlorite from corrosive slurries for hypochlorite bleach. Here the problem was to find a construction material for the unit able to withstand the highly corrosive effects of strong hypochlorite solutions. Corrosion-resistant components, ordinarily used, developed severe pitting corrosion from chloride ion attack in a matter of weeks.

After testing many metals, titanium was selected and adapted to equipment used in the most critical operations. The titanium unit at Pennsalt has been in operation for seven months and it still shows no sign of corrosion. Tool markings left by

machining operations are still clearly visible on titanium parts.

Titanium again solves a corrosion problem by extending the life of essential equipment. If severe corrosion is *your* problem, titanium may be the answer.

DU PONT CAN HELP YOU START YOUR EVALUATION TESTS NOW

As a pioneer in the commercial production of titanium sponge and development of industrial applications of titanium, Du Pont can offer you expert technical help. And Du Pont can put you in touch with manufacturers best equipped to work along with you. Considerable fabricating know-how and a wide variety of mill shapes are *now* available to help solve your corrosion problems. For more detailed information on titanium, just check coupon below.



E. I. du Pont de Nemours & Co. (Inc.)
Pigments Department C-11
Wilmington 98, Delaware

☐ Please send me your new technical bulletin on the corrosion-resistant properties of titanium.

☐ Please send me your general booklet on titanium.

I am interested in using titanium for: _____

Name _____

Firm _____

Position _____

Address _____

City _____

State _____

TITANIUM SPONGE

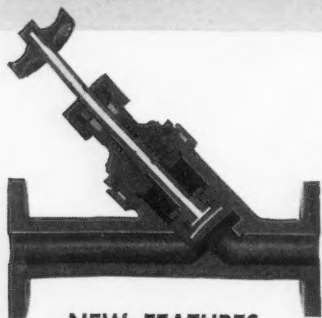
PIONEERED COMMERCIALLY BY DU PONT



REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY

IMPROVED and EXPANDED Line of Hard Rubber Valves for CHEMICAL APPLICATIONS



NEW FEATURES

Improved packing of DuPont Teflon is now used in all Luzerne valves.

New line of flanged valves has been added to existing Luzerne line of threaded screw straight away, screw stem angle and globe valves.

This gives you a complete selection of hard rubber valves. Luzerne valves are available in standard hard rubber compounds or in heat resistant Buna-N synthetic compounds for temperatures to 225° F.

PIPE AND FITTINGS



Luzerne offers a complete line of standard and heat resistant hard rubber pipe and fittings carried in stock in all sizes from 1/4" to 4". Sizes over 4" on special order.

Write for complete information or send us your specific hard rubber problem for analysis by our engineering department



The LUZERNE RUBBER CO.

300 Muirhead Avenue Trenton, N. J.

— Sales Representatives —

ALBERT J. COX CO.
Chicago, Ill.

R. C. FOLTZ CO.
Houston, Texas

L. A. RUBBER & ASBESTOS WORKS
Los Angeles, Calif.

details of theory or applications. Potentialities in analytical and physical chemistry are indicated. The following topics are discussed: irreversible, kinetic and catalytic currents in conventional polarography; voltammetry with continuously changing potential (oscillographic polarography); voltammetry with periodically changing potential (electrolysis with superimposed alternating voltage); voltammetry with constant current; voltammetry with stirred solution; voltammetric titrations. 163 references.—MA. 11453

2.3.4

Procedure for Studying the Corrosion of Iron Powder. I. V. KROTOV. *J. Applied Chem., USSR* (Zhur. Priklad. Khim.), 28, No. 12, 1302-1307 (1955) Dec.

Three methods are presented for determining amounts of rust: evolution of hydrogen by sample in acid; volumetric analysis of iron in surface rust upon treatment in 2 percent sulfuric acid; and measurement of sample's weight gain on rusting. Type of measurement based on type of corrosion. Two figures, two references.—ATS. Translation available: Associated Technical Service, P. O. Box 271, East Orange, New Jersey. 11428

2.4 Instrumentation

2.4.2, 2.3.4

High Pressure Loop Design for Studies of Reactions Between Heated Metals and High Temperature Water. D. C. KAULITZ AND J. E. MINOR. Hanford Atomic Products Operation, U. S. Atomic Energy Commission Pubn., HW-38876, Sept. 9, 1955, 20 pp.

A high pressure facility has been constructed to study the reactions between high temperature water and metal specimens heated well above water temperature. Location of the reaction chamber in a bypass section cut off from the loop proper by two air-operated valves permits the specimen to be protected by an inert atmosphere while the water is heated. Water temperatures and pressures up to 300C and 2000 psi and specimen temperatures up to 800C, are utilized. (auth.)—NSA. 11435

2.4.3

Van de Graaff Radiography of High Density Alloys. R. E. DROEGKAMP. *Non-destructive Testing*, 13, No. 5, 27-30 (1955) Sept.-Oct.

High density objects, such as some induction-melted uranium-base alloy ingots, or a zirconium alloy 4 inches thick which could not be X-rayed with a 250 kv tube type machine, were radiographed using a 2MeV Van de Graaff electrostatic generator. Radiographic results were not so good as those obtained by using conventional X-ray technique on low density materials; suggestions are made for achieving comparable quality.—BNF. 11461

2.4.3

New Applications for Ultrasonics in the Testing of Materials. J. BRIGG. *Rev. universelle Mines*, Sec. ix, 11, No. 4, 137-151 (1955).

The principles of ultrasonic flaw detection are described, its position in the general field of non-destructive testing is clarified, materials to which the technique is applicable are listed and typical applications such as testing welds and measuring corrosion are considered. The scope of the method is illustrated by a

useful table showing parts, their material of construction, maximum weight and the type of fault to which ultrasonic testing can be applied. 17 references.—MA. 11329

2.4.2, 2.3.7

Temperature and Pressure Measurements. M. SCADRON. *Aero-Research Instrument Co. Jet Propulsion*, 25, No. 9, Pt. 2, 3S-45S (1955) Sept.

Discusses probes used in testing research aircraft. Simple water-cooled total pressure rake for measuring total pressure distribution in afterburner or ramjet is made of aluminum, stainless steel or brass. Hot liquid sodium measurements are made through use of swaged magnesium oxide insulated chrome-alumel wire. Universal type thermocouple probe for measurements in fuel, hydrogen peroxide, LOX, liquid nitrogen, liquid sodium, gas generators and oil is stainless steel. To measure total temperature of gas streams at 2800-3000F, platinum-platinum-rhodium thermocouple wire with zirconium insulation is used. Above 3000F thermocouple may be iridium-iridium-rhodium or platinum-platinum-rhodium.—INCO. 10975

2.4.2, 2.3.7, 2.3.4

Furnace Tests Metals vs. Corrosives. PAUL C. ZIEMKE. *Chem. Eng.*, 62, No. 9, 212-214 (1955) Sept.

An oscillating furnace has been developed to study the effects of alternate heat and cold on metals in contact under turbulent conditions for a wide variety of corrosive materials. It is possible to stimulate turbulent flow conditions with this apparatus without the use of pumps.—NSA. 11052

2.4.3

The Scope of Gamma-Radiography. L. MULLINS. *J. Brit. Inst. Radio Engrs.*, 15, No. 3, 131-141 (1955) March.

A survey based on 24 references. It is concluded that increasing availability of γ -ray sources has extended scope of industrial radiography, owing to greater thickness penetration, same effect can be achieved by high energy X-rays (1000-2000kV) which also reveal fine defects, but cost and immobility of such X-ray units at present are big disadvantages. Sources, scope and application of gamma radiography to inspection of castings (thick sections of heavy metals, e.g. iron, steels) and welds is discussed.—BNF. 10919

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.1, 2.3.6, 2.3.9

Electron Microscopy and Electron Diffraction in the Service of Corrosion Research. (In German.) W. FEITKNECHT. *Umschau Wiss. u. Tech.*, 55, No. 18, 556-558 (1955) Sept.

Research on the structure of minute corrosion deposits on zinc in sodium chloride solution. Micrographs, photograph.—BTR. 11408

3.2.2, 6.3.6

Dealuminization of Aluminum Bronze. MORTIMER SCHUSSLER AND D. S. NAPLITAN. *Corrosion*, 12, No. 3, 107-112 (1956) March.

Though rarer than dezincification in brass, dealuminization can occur in alu-

Cut maintenance costs. . . increase pipe life



with proven performance . . .

On job after job, pipe line men rely on these
Johns-Manville Asbestos Pipe Protection Materials
 to fight pipe line corrosion:



Transshield® Asbestos Felt

This low-cost pipe line protecting wrapper is specially designed to increase pipe life under average soil conditions. It is reinforced with continuous glass yarns, parallel spaced on $\frac{1}{4}$ " centers to give tear-free application strength. Made of coal-tar saturated asbestos, it acts as a lasting barrier to shield pipe line enamels from earth loads and soil stresses.



#15 Asbestos Pipe Line Felt

A heavy-duty material particularly suitable for severe soil conditions or where a heavier material than J-M Transshield is desired. Provides long life, toughness, flexibility, resistance to rot, decay, cracking, and impact. J-M #15 Asbestos Felt now protects more than 100,000 miles of oil and gas pipe lines. Widths 2" to 36". Rolls any length desired.

For further information about Johns-Manville Products for Pipe Line Protection, write to Johns-Manville, Box 60, New York 16, N. Y.; in Canada, Port Credit, Ontario.



Johns-Manville

PRODUCTS FOR PIPE LINE PROTECTION

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members and Companies seeking employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Advertisements to other specifications will be charged for at \$10 a column inch.

Positions Available

Well-known, Established paint manufacturer Metropolitan New York introducing recently developed liquid anode seeks chemical engineer to support further research and promotion in the field of cathodic protection. Opportunity offers excellent compensation, challenging future. CORROSION, Box—56-16.

Experienced Corrosion, cathodic protection engineers wanted for work in South and Southwest. Excellent starting salary, profit sharing bonus and company stock participation program offered. Corrosion Rectifying Co., Box 19177 Houston, Texas.

Director of Research position available with association for painting of steel. Research and field experience desirable. Write stating education, experience, abilities, publications, salary desired and references. Dr. Joseph Bigos, Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

Corrosion Engineer for Houston, Texas area, preferably familiar with the theory and application of protective coatings; to join rapidly expanding application contractor. Write Box 56—17, CORROSION.

Sales Engineer—Outstanding opportunity for corrosion engineer interested in sales. A thorough knowledge of protective coatings is required. Territory open in mid-western states for well known paint manufacturer. Replies confidential. CORROSION, Box 56-18.

CORROSION ENGINEER

Engineer to assist chief corrosion engineer in solving corrosion Problems and applying cathodic protection on gas transmission pipe lines. Give qualifications, references and salary expected.

Write:

Chief Corrosion Engineer
Mississippi River Fuel Corporation
407 North 8th St.
St. Louis 1, Missouri

CORROSION ENGINEER

College degree preferred, but would consider men with less education, experienced or interested in cathodic protection of bare and coated pipelines.

Immediate location in Indiana or Ohio. Send full particulars regarding education, experience, salary requirements, and photograph. Replies held in strictest confidence. Write:

WILLIAM H. WEBER
Sohio Pipe Line Company
7438 Forsyth
St. Louis 5, Missouri

minum bronze and such attack can constitute a failure hazard. A case of a dealuminization failure in a cylinder valve is cited. This failure was attributable to selective corrosion of the aluminum-rich phase in an aluminum silicon bronze having a duplex structure.

In the process of selecting a more suitable material for the cylinder valves, dealuminization studies were carried out on samples of single and two phase aluminum bronzes which were exposed to aqueous hydrofluoric acid, the corrosive agent to which the valve failures were attributed. Alpha aluminum bronze suffered no harmful attack; the duplex aluminum bronze, regardless of its heat treated structure, suffered a selective dealuminization attack which caused a severe loss in ductility. 11157

3.2.2, 8.4.3

How to Reduce Hydrogen Attack. GORDON R. KING, *Petroleum Refiner*, 35, 124-128 (1956) Jan.

Although hydrogen attack in the oil industry cannot as yet be eliminated, it can be reduced. Locally, concrete protective liners seem most economical. Generally, water washing and air injection methods have proved effective. Diagram, graph, photographs, 32 references.—BTR. 11370

3.2.3, 2.4.2, 2.3.5, 5.9.2

Composition of the Scale Forming on Hot Rolled Strips and Sheets. (In German.) WALTER FACKERT, *Stahl und Eisen* 75, No. 25, 1705-1710 (1955) Dec. 15.

Report No. 30 of the Cold Rolling Mill Committee of the Verein Deutscher Eisenhüttenleute. Relations in the scale formation on steel surfaces. Variables influencing upon these relations and reasons for the necessity of acquiring a sound knowledge on the structure of the scale film. Potential methods. Short review on the present state of the technique according to the literature and conclusions drawn therefrom for the operation of a pickling plant giving the answer to five questions raised. Description of a measuring device of own design for recording the dissolution lines of scale. Working method of the device. Proof of the exactness of the recorded dissolution lines by their reproducibility. Application of the measuring device to the determination of the scale structure of six hot-rolled strip sections of different origin.—SE. 11403

3.2.3, 3.5.9, 1.6, 6.5

High Temperature Scaling of Nickel-Chromium, Iron-Chromium, Copper-Chromium and Copper-Manganese Alloys. Third and Final Technical Report (for) March, 1955 to November, 1955 (on) Thermodynamics and Kinetics of Metals and Alloys. C. A. BARRETT, E. B.

Positions Available

Corrosion Engineer—Major oil company has opening in Venezuela for corrosion engineer. Experienced application cathodic protection, pipe coatings, etc. Age to 40. Mail resume to P. O. Box 35, Bowling Green Station, New York 4, N. Y.

Positions Wanted

Corrosion Engineer—Five years experience on design and installation cathodic protection systems on pipelines. Available January 1. CORROSION, Box 56-15.

EVANS AND W. M. BALDWIN, JR. Case Institute of Technology, December, 1955, 64 pp.

The high temperature scaling behavior in air of nickel-chromium, iron-chromium, copper-chromium and copper-manganese alloys was studied. Scaling rates and scale compositions were determined as a function of alloy composition. Chromium additions exceeding about 10 percent effected a tremendous decrease in the scaling rate of nickel and of iron. The best scaling resistance of both the nickel-chromium and iron-chromium alloys was associated with about 20-25 percent chromium and was characterized by a scale consisting essentially of Cr_2O_3 , not the spinel oxide. These findings paralleled those previously obtained with cobalt-chromium alloys. The scaling rate at this critical concentration was independent of the base metal—be it nickel, iron or chromium. Chromium additions of up to 40 percent to copper had virtually no effect on the scaling resistance. The scale formed on these alloys consisted essentially of copper oxide(s). Copper-manganese alloys exhibited a U-shaped curve relating scaling rate and alloy composition. The best scaling resistance was associated with a critical concentration of about 25 percent manganese, corresponding to the minimum concentration of manganese necessary for the exclusive formation (or nearly so) of manganese oxides in the scale. The theoretical considerations put forth by Wagner were utilized as an aid in interpreting the scaling behaviors. (auth).—NSA. 11312

3.2.2

Why the Forging Failed. *Steel*, 137, No. 21, 96-98 (1955) Nov. 21.

Failure of steam turbine shaft manufactured by Allis-Chalmers of nickel-molybdenum-vanadium steel due to hydrogen embrittlement. Central portion of shaft (between shrunk-on-rings) split into four almost identical quarters. Rupture started in area of shaft near the bore which showed abundance of hydrogen flakes and progressed by brittle fracture. Indications spotted in ultrasonic tests in 1951 and classified as harmless inclusions and stringers would today be regarded as significant danger points, due to increased understanding of ultrasonic techniques. Nominal composition of steel was 2.5-3.5 nickel, 4-6 molybdenum, minimum of .05 vanadium, .25-.75 chromium and .25-.35 carbon. Microstructure of typical crack near mid-radius of forging is shown.—INCO. 11001

3.2.2, 6.4.2, 3.7.1

Formation of Etch Pits on Slip Lines in Aluminum. G. WYON AND J. M. MARCHIN, *Phil. Mag.*, 46, No. 381, 1119-1122 (1955) Oct.

Experiments were conducted to establish whether the localization of etch pits on slip lines of aluminum is solely governed by dislocations, or whether it is also affected by other factors, such as impurities or the microgeometry of the surface investigated. For this purpose samples of recrystallized and electropolished high-purity aluminum were slightly deformed, etched and treated by a wetting agent. According to the observations made the conclusion is drawn that dislocation alone cannot modify the reactivity of aluminum with regard to the acid reagent sufficiently to give rise to etch pits at the points of emergence

of the dislocations. But in aluminum alloys with a small amount of alloying elements and aged after deformation it is possible to demonstrate the alignment of etch pits of slip-band markings, even in the areas of crystals lying under the surface.—ALL. 11049

12.3, 3.8.4

Structure of Rust with Respect to Adsorption. Part II. (In Russian.) V. V. SKORCHELETTI AND S. E. TUKACHINSKII. *1. Applied Chem., USSR* (Zhurnal Prikladnoi Khimii), **28**, No. 6, 651-655 (1955) June.

Structure of hydrated iron oxides (with respect to adsorption of water) is affected by conditions of formation. The corrosion threshold of metal coated with rust is determined by the structure of the latter. Mild steel specimens were used. 7 figures, 9 references.—ATS. Translation available: Assoc. Tech. Services, P. O. Box 271, East Orange, New Jersey. 11013

3.4 Chemical Effects

3.4.8, 3.5.9, 8.4.3

High Temperature Hydrogen Sulfide Corrosion in Thermoform Catalytic Reformers. A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry from: Socony Mobil Oil Co., Inc., Research and Development Laboratory, Paulsboro, N. J. E. B. BACKENSTO, R. D. DREW, R. W. MANUEL AND J. W. SJOBERG. *Corrosion*, **12**, No. 5, 235t-244t (1956) May.

High temperature hydrogen sulfide corrosion is a serious problem in commercial reforming units. Corrosion tests conducted in two Thermoform catalytic reformers, which handle widely different type stocks, have shown that carbon and low chrome steels commonly used for construction in the petroleum industry will not resist hydrogen sulfide attack under the high temperature conditions of the process. The commercial tests confirmed laboratory results which indicated that only the 18-8 chrome-nickel and higher alloys show good resistance to this type of corrosion.

In addition to proper selection of alloys, altering the environment by reducing hydrogen sulfide concentration and the use of aluminum coated steels have been successful in combating this type of corrosion. 11265

3.5 Physical and Mechanical Effects

3.5.1, 5.11

Resistance of Materials to Mechanical Corrosion. RUSSELL W. HENKE. *Product Engineering*, **27**, No. 1, 194-197 (1956) Jan.

Reviews causes of stress-corrosion, corrosion fatigue, impingement erosion and fretting; and presents guides to the choice of the most resistant materials and remedies possible in design. Photographs.—BTR. 11368

3.5.3, 2.3.7

On the Physical Nature of Cavitation Erosion. (In Russian.) L. A. GLIKMAN, V. P. TEKHT AND YU. E. ZOBACHEV. *Technical Physics, USSR* (Zhur. Tekhn. Fiziki), **25**, No. 2, 280-298 (1955).

Various materials, including cast iron, high-tensile steel, plain-carbon steels of various compositions, austenitic steel and

an iron-manganese-aluminum brass were tested for resistance to cavitation produced by a magnetostriction oscillator. Results obtained were as follows: 1) Microscopic study of the metal surface during tests showed the growth of a surface layer of plastically deformed metal 20-40 μ thick. As the test went on, microcracks and ridges were seen to form. When the specimen was not all of the same strength, cavitation erosion always began at the weakest part. 2) Microhardness tests showed a hardening of the surface layer. The hardness of low carbon and austenitic steels increased by 20-50 percent during test; other materials hardened by 10-17 percent. 3) X-ray examination confirmed the microscopic and microhardness evidence of the progressive formation of a worked layer. 4) Resistance to cavitation is determined not only by the macroscopic

properties of the specimens but also by the properties of any microscopic inclusion. 5) As would be expected, the progress to destruction by cavitation is generally similar to that in fatigue and the influence of corrosion is similar also.—MA 11407

3.5.8

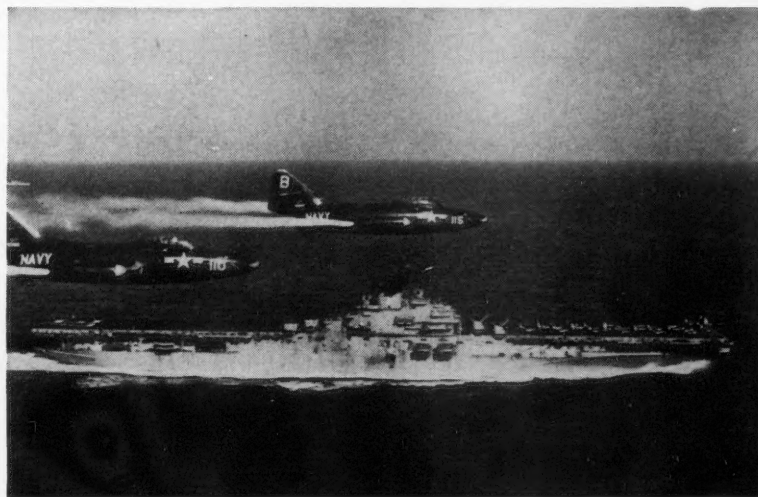
Characteristics and Prevention of Fretting Corrosion. R. B. WATERHOUSE. *Machine Design*, **28**, 104, 106, 108 (1956) Jan. 26.

General considerations of the damaging results and preventive measures.—BTR. 11350

3.5.8

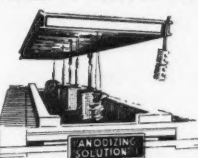
Fatigue: What We Do and Don't Know About It. G. R. GOHN. *SAE Journal*, **63**, No. 9, 38-44 (1955) September.

General review of fatigue phenomena:



CHROMIUM CHEMICALS IN ACTION

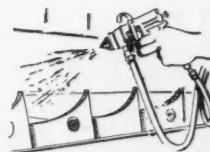
The useful life of modern jet aircraft has been appreciably prolonged through the application of effective corrosion inhibitors. Chromium Chemicals in various forms are used at many stages of jet plane production.



Anodizing aluminum alloy parts with chromic acid forms one of the most effective protective coatings known today. Furthermore, it is an excellent base for the customary zinc chromate primer. Steel and magnesium assemblies also are painted with zinc chromate... and before magnesium castings are primed they are dipped in a bichromate bath.

These illustrations are examples of the ability of Chromium Chemicals to inhibit and prevent corrosion.

Besides supplying many industries with superior quality chromium chemicals, Mutual offers information on the numerous other ways that these chemicals help to protect valuable materials and equipment. So, if you are in doubt about the best way to solve your corrosion problem, contact Mutual.



Sodium Chromate • Chromic Acid • Sodium Bichromate
Potassium Bichromate • Potassium Chromate

MUTUAL CHEMICAL DIVISION

ALLIED CHEMICAL & DYE CORPORATION

99 PARK AVENUE • NEW YORK 16, N. Y.



causes of fatigue, defects in strain hardening and dislocation theory, no relationship to other mechanical properties, S-N curves and their interpretation, some factors that affect fatigue and reduction of fatigue by shot peening.—BNF. 11384

3.5.8

Stress Corrosion. (In German.) KURT MATTHAES. *Z. Metallkunde*, 47, No. 1, 37-42 (1956) Jan.

An analytical treatment of stress corrosion is presented. The effect of two independent factors: chemical attack and mechanical load is discussed and it is stated that in the stress corrosion of magnesium-aluminum alloys the mechanical factor predominates. However, stress corrosion of aluminum-copper-magnesium alloys is influenced by other external factors also, such as phase-transition, chemical composition of the alloy and its heat treatment. For the combined effect of the duration of the heat treatment, ϕ , and its temperature T the relationship $\phi = \exp. 15,500/RT$ holds.—ALL. 11347

3.5.8, 2.3.7

Effect of Residual Stresses in Surface of Metals upon Wear Resistance. P. E. DYACHENKO AND T. V. SMUSHKOVA. *Vestnik Mashinostroeniya*, 35, No. 3, 38-40 (1955).

Lack of consistent literature data on effect of residual stresses in metal surfaces on wear resistance. Authors' study of influence of such stresses (tensile and compressive) in surface zone, 40-200 micro-inches thick, of steel rings upon the latter's wear resistance and of variation of residual stresses and strain hardening of surface zone while subject to wear. Experimental procedure in setting up surface stresses (by high-speed machining), measuring their magnitude, and testing the specimens of wear. Steels used for study: 0.20 percent carbon and 0.45 percent carbon steels; chromium-nickel-molybdenum structural steel. Distribution of residual stresses in surface. Wear curves; distribution of residual stresses. Mechanism of interaction between pre-existing and wear-produced stresses. Change in stress distribution induced by wear. Translation available: Henry Bratcher, P. O. Box 157, Altadena, California. 11459

3.5.9, 1.6

High Temperature Technology. I. E. CAMPBELL, Editor. Book, 1956, 526 pp. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York.

Contributions on various aspects of the technology related to high temperature by 35 experts in several fields are collected. The book, sponsored by the Electrothermics and Metallurgy Division of The Electrochemical Society, is the outgrowth of several symposia on the subject. In general, consideration is given to service at temperature above 1500C but much material in the materials and methods section discusses processing at moderate temperatures.

Part II, Materials, discusses the principal materials available for high temperatures service, including metals, oxides and cermets. Under the title of Methods discussions include sintering and means of achieving high temperatures, while the last section considers methods of measuring the properties of materials exposed to high temperatures.

An author and subject index are included. 11357

3.5.9, 3.4.6, 3.4.8

What Happens in H₂-H₂S Corrosion. E. B. BACKENSTO, R. D. DREW AND C. C.

STAPLEFORD. Paper before NACE, Houston, October 21, 1955. *Petroleum Refiner*, 35, No. 1, 147-150; disc., 150-151 (1956) January.

Discusses the combined effects of H₂-H₂S at elevated temperatures on various steels as tested in commercial reforming units, laboratory pilot units and laboratory corrosion units. Typical corrosion rates of chromium steels at 1175F and 175 psig and 985F and 485 psig are plotted against chromium content (data for 18-8, 25-12 and 25-20 included). Tests at low hydrogen sulfide concentrations showed thin film of powdery corrosion products on steels with up to 9 percent chromium and no scale on chromium-nickel alloys. Plot of corrosion rates for 0.9 percent chromium steels vs time of exposure shows that corrosion is high after 24 hours and drops off rapidly after 100 hours. Tests with aluminum coating were made. Calorized (aluminum diffusion process) carbon steel showed no attack while aluminum overlay of metalized and aluminum dipped specimens disappeared.—INCO. 11315

3.5.9, 5.4.2, 5.3.2

Ceramic and Metal Coatings for High Temperature Aircraft Materials. J. V. LONG. Paper before Aircraft Research Seminar, Symp. on High Temperature Materials for High Speed Aircraft, Univ. of Calif., Los Angeles, December 8, 1954. Society of Automotive Engrs., Special Pubn. No. 128, 1955, 6+ pp.

Discusses problems and new developments in protective coating field. Fired-on ceramic and diffused, aluminum-metal coatings appear to be most useful for general production work. Cermets will probably be next step in field. A nickel-magnesia cermet coating shows promise. Useful cermet coatings can be made by adding powdered metals to a good high temperature ceramic coating. Micro-braz may be added to Bur. of Standards' frit and fired on AISI 321, producing a coating with good erosion resistance, but poor sulfur and lead combustion products resistance due to high nickel content. Outstanding results have been reported for aluminum-coated nickel blade alloys. Results of stress-rupture tests show that aluminumized nickel-base alloy provides a 10-fold increase in stress-rupture life of part. Illustrations, photomicrographs.—INCO. 11163

3.5.9, 6.3.4, 1.6, 3.8.4

High Temperature Scaling of Cobalt-Chromium Alloys. Technical Report No. 2 for March, 1955, to September, 1955. E. B. EVANS, C. A. PHALNIKAR AND W. M. BALDWIN, JR. Case Inst. of Technology, Cleveland, October, 1955, 58 pp.

Scaling rates and scale compositions of cobalt-chromium alloys were determined in the temperature range of 900 to 1200C. At any given temperature the scaling rate increased with low chromium additions, then dropped precipitously with further additions reaching a minimum at about 25 percent chromium. Thereafter the scaling rate again increased approaching the scaling rate of chromium as the upper limit. Above a critical concentration of about 25 percent chromium, the scale consisted exclusively of chromic oxide. Below this critical concentration, complex scales consisting of the oxides of both cobalt and chromium were formed. The best scaling resistance was associated with a scale consisting predominantly of chromic oxide not spinel. Schematic isothermal sections of the deduced cobalt-chromium-oxygen phase diagram were applied as an aid in interpreting the scaling behavior. It is

concluded that none of the current theories of scaling of alloys describes the present case. (auth.)—NSA. 11469

3.5.3

Studies on Corrosion at Power Generating Stations Using Acidic River Water. (13th Rept.). On Cavitation Corrosion. S. SHIMODAIRA, Y. SAWADA AND N. OOTANI. *J. Japan Inst. Metals*, 19, No. 3, 209-212 (1955) March.

The damage to carbon steels by cavitation in acid aqueous solutions was studied. Cavitation was produced by ultrasonics. The experimental results showed that the damage by cavitation was due to electrochemical reaction and the direct blow of water. These actions occurred simultaneously, and the former was rather more important than the latter in oxidizing acid solutions. Resistance to cavitation increased with corrosion resistance and hardness.—JSPS. 11005

3.5.3, 5.11, 7.1

Hydraulic Method of Protecting Turbines from Cavitation Erosion. (In Russian.) K. K. SHAL'NEV. *Vestnik Akad. Nauk SSSR* (News of the Academy of Science), 25, No. 9, 50-52 (1955) Aug.

Technological methods of protection involve use of high-alloy metals in the building or repair of turbines and turbine parts. However, the hydraulic methods produce better design and smoother, streamlined parts. Diagrams.—MR. 11006

3.5.8

Friction & Fretting with Solid Film Lubricants. E. E. WEISMANTEL. *Lubrication Eng.*, 11, No. 2, 97-100 (1955) March-April.

Effect of dry film type lubricants on occurrence of fretting and upon frictional properties of materials. Significant difference in performance of compounds indicated by data, properties being dependent upon both binders and lubricating solids. Pure lubricants performed as well as best of complex compounds. Consideration of operating conditions and expected service when selecting lubricant. Bibliography.—BL. 11056

3.5.8

Residual Stresses. Am. Soc. Metals Ctte. on Residual Stress. *Metal Progress*, 68, No. 2-A, 89-96 (1955) August 15.

This supersedes the article on residual stresses in the 1948 ASM Metals Handbook. A concise general discussion including residual stresses arising from effects of thermal expansion (spot or butt welding, quenching, precipitating, bulk transformations, built-up shafts, castings); from mechanical processes; and in electroplated coatings. Effects of residual stress include warping, breaking under various conditions, fire-cracking, etc. Relation between fatigue and residual stresses is controversial. Relief of residual stresses by heat treatment of mechanical methods (with a table of temperatures and times of stress-relief treatments for ferrous and non-ferrous alloys). Measurement of residual stress.—BNF. 10905

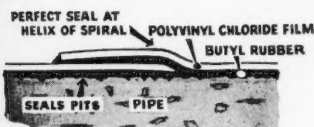
3.5.8, 2.3.7

Residual Stresses in Castings. A. PORTEVIN AND J. POMEY. International Foundry Congress (London) Paper No. 1120, June, 1955, 10 pp. *Foundry Trade J.*, 99, 9-17 (1955) July 7; *Fonderie (France)*, No. 114, 4585-4594 (1955) July.

Procedures for revealing, measuring

You get these
extra advantages

with
PLICOFLEX
pipeline tape
coatings!



1. NO MOISTURE MIGRATION . . . The sketch above shows how the outstanding cold-flow properties of the butyl rubber provide a perfect seal at the helix of the spiral overlap. Air and moisture are literally squeezed out . . . can't get in again . . . can't migrate under the protective coating.

2. INCREASED SOIL STRESS RESISTANCE . . . Here's an added bonus created by the unique Plicoflex laminated construction . . . available *only* in Plicoflex!

3. HIGHEST SHOCK-IMPACT RESISTANCE . . . Made of tough polyvinyl chloride film laminated to butyl rubber, Plicoflex Tapes offer the extra protection of more-than-double thickness together with resiliency which prevents damage during backfilling operations.

4. STRONGER PERMANENT BOND . . . Plicoflex sets up quickly. Exhaustive tests show that within two weeks after application, Plicoflex "cures" to form an *inseparable* bond to the pipe, even on irregular surfaces. Moreover, the tape itself will not delaminate in use.

5. UNIFORM THICKNESS . . . Rigid factory inspection assures the user that the Plicoflex system of coatings will be of uniform quality and uniform thickness. Thus the user knows he can depend on Plicoflex to give equal all-over protection.

6. SELF-HEALING PROPERTIES . . . The cold-flow characteristics of butyl rubber provide another bonus, flowing into and sealing holidays that may occur in the tape film due to mechanical damage.

7. BUILT-IN COLOR-CODING . . . Available in black, white, and 6 brilliant colors, Plicoflex Systems provide a virtually maintenance-free method of color coding for above-ground plant installations. No painting required — the color is *in the tape*!

8. LOW COST . . . Unique Plicoflex application systems cut coating manpower requirements to a minimum. You benefit from lower first cost as well as lower maintenance costs.

9. ADHESIVE PRIMERS . . . Factory-produced to thoroughly tested formulae and rigidly inspected for quality and uniformity, Plicoflex adhesive primers are available to suit practically every normal requirement.

10. EXPERIENCE . . . Plicoflex systems have been engineered and produced by men long experienced in corrosion protection of pipelines. This is our *primary interest* — not a by-product of other interests.

Let your Plicoflex representative show you how you can put these **PLICOFLEX PLUS VALUES** to work for you . . . today! Or write for Plicoflex Data File.



PLICOFLEX

TRADE MARK

PLICOFLEX, INC.

1566 East Slauson Avenue, Los Angeles 11, Calif. • LUdlow 3-4741
5830 Harvey Wilson Drive, Houston, Texas • WAlnut 8-3343

Good jobber territories are still available . . . inquiries invited

NACE CORROSION ABSTRACT CARD SERVICE

• Don't you wish you had some convenient means of learning about solutions to corrosion problems reached by others? Don't you wish you had some way to find reports of work done on corrosion problems like the ones you face daily? Wouldn't you like to be able to learn what solutions have been tried already—which ones have failed, and why and which ones have proved successful? Wouldn't you like to have some means of selecting from the mass of printed information on corrosion the articles that pertain only to your own problems?

INVESTIGATE

NACE's Corrosion Abstract Card Service which provides you with about 2000 cross-indexed cards a year that can be sorted conveniently by semi-automatic methods. These versatile cards can be indexed according to your needs and interests. They come pre-punched with NACE's indexing, but you can add your own if desired.

Get the whole story about this useful service. Ask for a description of the index, sample of the card used and other information. If you are engaged in corrosion control work of any kind, these cards will be useful to you. The subscription cost is nominal. Subscriptions are being accepted now for calendar 1957.

Write to

**NATIONAL
ASSOCIATION
of
CORROSION
ENGINEERS**

1061 M & M Bldg., Houston, Texas

and classifying the presence or state of residual stresses, their distribution and intensity; origin and modification of state of stress; influence of stresses on existence, behavior and use of metallic parts, with particular reference to castings. Steels and non-ferrous metals are quoted as examples.—BNF. 10948

3.5.8, 3.7.3

How to Prevent Fatigue Failures. J. VIGLIONE. Naval Air Material Center. *Product Eng.*, 26, No. 10, 174-178 (1955) Oct.

Practical, non-metallurgical discussion of causes for fatigue failures covers effects of surface finish, surface treatments such as cold working, carburizing, nitriding and shot peening, plated coatings, corrosion, inclusions, speed of loading, size and geometric factors, temperature and joining methods. Metallic coatings generally reduce fatigue strength of steel. Bright nickel increases fatigue strength of aluminum. Design considerations are given for increasing fatigue life of welded and riveted joints and bolted connections. Tables of fatigue ratios for spot welds and for bolts include data for stainless steel.—INCO. 11033

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.3

The Influence of Some Chemical and Physical Factors on the Formation of Deposits from Residual Fuels. P. T. SULZER. Paper before Am. Soc. Mech. Engrs., Ann. Mtg., Gas Turbine and Fuels Div., N. Y., November 28-December 3, 1954. *Trans. ASME*, 77, No. 7, 995-1001 (1955) October.

Theory and experiments on the formation of ash during combustion in industrial gas-turbines are discussed and illustrated with practical examples. Measurements of ash-deposit formation as a function of temperature, pressure, excess air, fuel-ash content and test duration, are shown graphically and summarized in a formula.—INCO. 11015

4.2.3, 7.4.1

Influence of Fine Particles on Corrosion of Economizer and Air-Preheater Surfaces by Flue Gases. PETER HOBSON. *Trans. Am. Soc. Mech. Engrs.*, 77, 279-285; disc., 285-286 (1955) April.

A qualitative test of the formation temperature, extent and nature of deposits from cleaned and dirty gas showed that deposits tend to build up in a narrow range and that cleaning the gas greatly decreases the rate of deposit build-up. Table, micrographs, diagrams, photograph. 12 references.—BTR. 10031

4.2.3, 3.5.9, 7.4.1

The Use of Additives for the Prevention of Low-Temperature Corrosion in Oil-Fired Steam-Generating Units. E. C. HUGH and E. C. PIOTTER. Paper before ASME, Ann. Mtg., November 29-December 4, 1953. *Trans. Am. Soc. Mech. Engrs.*, 77, No. 3, 267-274; disc., 274-278 (1955) April.

Low-temperature corrosion caused by the presence of sulfur trioxide in the combustion gases of oil-fired steam-generating units is discussed. Sulfur trioxide combines with water vapor to form sulfuric acid on cooler surfaces of the unit. Methods of prevention of corrosion include choice of materials, various coat-

ings, air-heater design to increase metal temperature and use of additives. Use of dolomite is stressed as economically feasible and recommended where corrosion or pluggage is a problem. Dolomite reduces amount of sulfur trioxide in flue gas and quantity of ash depositing in air heater. Equipment for dew-point measurement is described and data for tests conducted at Florida Power Corp. plants are tabulated. Graphs, bibliography.—INCO. 10041

4.2.3

Sulphur Dew-Point Corrosion in Exhaust Gases. R. L. CORR. *Trans. Am. Soc. Mech. Engrs.*, 78, 89-94 (1956) January.

Corrosion can be limited by using corrosion-resistant alloys, using low-sulfur fuels and by keeping surface temperatures above the acid-water dew point. No available coating materials adequately protect heat-exchanger surfaces or compressor blades at low temperatures. Diagram, graphs, photographs, tables. 7 references.—BTR. 11360

4.3 Chemicals, Inorganic

4.3.2, 8.8.1

Corrosion by Nitric Acid. A Progress Report by NACE Task Group T-5A-5 on Nitric Acid. JAMES L. ENGLISH, Chairman. *Corrosion*, 12, No. 6, 65-68 (1956) June.

Two cases involving corrosion of nitric acid reboilers are described. In the first case the reboiler had been installed on a 40 to 50 percent nitric acid distillation column. It was found that preferential corrosion attack took place on weld craters which generally contained small hairline cracks. In the second case a nitric acid reboiler used in the purification and concentration of nitric acid failed by corrosion after being in service for a period of nearly one year. The possibility of hexavalent chromium formation during batch-type nitric acid reboiler operation was considered as a possible clue to the cause of failure of the second reboiler.

Air preheater corrosion encountered in the production of nitric acid is considered briefly. Information is given regarding corrosion of welds in equipment used to handle mixed solutions of nitric and sulfuric acid. Other matters discussed include corrosion of aluminum welds in boiling 98 percent nitric acid, cracking of Duriron flanges on paulling towers, vapor-phase corrosion above nitric acid solutions, effect of chlorides on corrosion by nitric acid, and presence of ferrite in austenitic stainless steel welds.

Reports are given of explosions occurring when titanium test specimens were used in conjunction with red fuming nitric acid. It is not definitely known just what causes such explosions, nor are there any well developed theories on the mechanism by which they occur. The use of zirconium in nitric acid solutions is described briefly. 11418

4.3.2, 4.3.6, 6.6.11

Corrosion-Chemical Behaviour of Non-Ferrous Metals in the Presence of Alkalimonofluorides and Alkalihydrogenfluorides. (In German.) W. KOHLER. *Werkstoffe u. Korrosion*, 6, No. 10, 478-486 (1955) October.

As the alkalimonofluorides and alkalihydrogenfluorides are widely used as wood preservatives especially on construction lumber, their corrosive effects on metals are of practical interest. Following a description of the corrosion-testing procedure and of the preparation

crease metal
ves. Use of
omically
ere corro-
Dolomite
oxide in flue
iting in air
oint meas-
a for tests
orp. plants
ography.—
10041

on in Ex-
t. Am. Soc.
) January,
sing corro-
sulfur fuels
tures above
o available
otect heat-
ssor blades
n, graphs,
ces.—BTR,
11360

A Progress
up T-5A-5
sh, Chair-
-68 (1956)

n of nitric
in the first
led on a 40
lation col-
ential corro-
raters which
ine cracks.
id reboiler
ncentration
n after be-
nearly one
alent chro-
type nitric
sidered as a
ture of the

untered in
considered
regarding
t used to
and sulfu-
ed include
boiling 98
f Duriron
apor-phase
ions, effect
nitric acid,
nitic stain-

ons occur-
ens were
ining nitric
just what
there any
mechanism
zirconium
ed briefly.
11418

ur of Non-
esence of
calihydro-
KOHLE,
10, 478-

nd alkali-
used as
on con-
ve effects
rest. Fol-
corrosion-
eparation

of the samples, the experimental results for various non-ferrous and light metals and alloys (including 99.0% aluminum, aluminum-magnesium-silicon alloy with 1.0% silicon and 0.7% magnesium and aluminum-magnesium alloy with approximately 3% magnesium and a commercial grade magnesium-manganese alloy containing 2.0% manganese) are given. Concentration of the attacking media, dimensions and surface properties of the samples, changes of weight, the rate of corrosion and the final findings concerning surface characteristics are tabulated. As an overall result it is reported that aluminum and aluminum alloys in most cases exhibit good resistance to corrosion by alkalimonofluorides and alkali-hydrogenfluorides, unless the concentration approaches 20% and the temperature is as high as 80°C. The magnesium alloy was found to be totally resistant under all the experimental conditions.—ALL, 10941

4.3.5, 1.4

A Bibliography of Corrosion by Chlorine. A Report of Technical Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry. (Compiled by Task Group T-5A-4 on Chlorine. R. I. Zimmer, Chairman.) *Corrosion*, 12, No. 3, 141t-148t (1956) March.

This report contains 86 abstracts of papers on corrosion by chlorine. It is indexed by materials and coded by the NACE Abstract Code.

4.4 Chemicals, Organic

4.4.6, 5.8.2

Effect of Peroxide Compounds on the Anti-Corrosive Character of Oils. S. SATO. *J. Chem. Soc. Japan, Ind. Chem. Section*, 58, No. 1, 26-27 (1955) Jan.

The effect of turbine oils containing benzoyl peroxide or methyl oleates on the corrosion of steel was determined by the water-drop corrosion method. Addition of 0.02-0.08% benzoyl oxide, in which the value of peroxide is 4.5-9.3%, inhibits considerably the corrosion of steel while in the case of methyl oleate, the larger the value of peroxide, the smaller the inhibitive power.—JSPS, 10983

4.5 Soil

4.5.2

The Ratio Water-Air as Important Factor of the Corrosion of Metals in Soil. T. MARKOVIC AND B. SRIBAR. *Zastita Materijala*, 2, 146-149 (1954); *Chem. Abstr.*, 49, 6071-6072 (1955). May 10.

Metals like iron and aluminum were immersed in soil and the current obtained in the chain platinum/soil/metal under nitrogen protection was measured. Soils rich in air and low in water (fine sand) and high in water and low in air (montmorillonite) do not corrode too much, but if the soil has sufficient water to form the electrolyte and sufficient air to form the depolarizer (ordinary clay), heavy corrosion will occur. 11116

4.6 Water and Steam

4.6.1

Corrosion in Borated and Deionized Water at Temperatures up to 500°F. WALTER K. BOYD AND ROBERT S. PEOPLES. *Battelle Memorial Institute. U. S. Atomic Energy Commission Publ.*, BMI-1047, October, 1955, 20 pp.

Stainless steels, beryllium and aluminum

how to CUT CORROSION LOSSES

a report by Koppers Company, Inc.



James Beaumont
Project Leader

How thick should a protective coating on above ground installations be? This is a question that is asked of our Technical Department quite often.

* * *

All other factors being equal, the thicker the protective coating, the longer its service life. Basically, the coating thickness required is dictated by the degree of protection desired and the conditions under which the coating system must perform. Specifically, you need to know the following things about each job: (1) What is the corrosive

environment . . . mild? . . . severe? . . . acid? . . . saline? (2) How long must the coating last? . . . is it practical to re-coat every year or are thicker, longer-lasting coatings desirable? (3) The roughness of the surface: since valley-to-peak distance may be as great as 8 to 10 mils, it is vital that peaks be fully covered to the specified thickness. (4) Finally, you should figure the cost of "down time" in terms of lost production.

Another factor in determining coating thickness is the accessibility of the structure. Our pre-coating surveys always include a careful analysis of inaccessible areas where a thicker coating is recommended simply to eliminate for as long as possible the need to re-coat the hard-to-get-at places. This reduces yearly costs by lessening chances of corrosion in places that are passed-by in routine inspections or that are inaccessible.

* * *

The "Steel Structures Painting Manual" (Vol. 1) points out that average industrial conditions warrant a 5-mil coating and severe corrosive conditions need a coating that *must* exceed 10 mils. Generally, our applications research corroborates these recommendations.

It should be remembered that the inherent characteristics of coating materials determine the maximum thickness to which they may be applied in a single coat. For example, some cold-applied coatings of coal-tar base give, in a single coat, a film up to eight times the thickness of ordinary paints. Coal-tar enamels, widely used for pipeline applications, can be applied much more heavily, normal thickness being between 60 and 100 mils. Of course these heavier single-coat thicknesses mean reduced application time and labor costs as well as longer life.

* * *

Every attempt should be made to "police" the application to make sure that the desired thickness is obtained. Checks on wet or dry film thickness can be made with mechanical, electrical or magnetic gauges designed for the purpose.

* * *

If you have specific problems on protective coating thickness . . . or any corrosion-control problems . . . we'd be glad to hear from you. Write to Koppers Company, Inc., Dept. 100L, 1301 Koppers Building, Pittsburgh, Pa. District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh and Woodward, Ala. In Canada: Koppers Products, Ltd., Toronto, Ontario and Edmonton, Alberta.



BITUMASTIC
REG. U. S. PAT. OFF.

COATINGS AND ENAMELS

alloys were studied. Photographs, micrographs, tables.—BTR. 11318

4.6.1, 6.2.2, 2.3.4, 1.6, 3.8.4

Corrosion of Iron in High-Temperature Water. Part I. Corrosion Rates by Hydrogen Evolution at 240 to 360°C. Part II. Kirkendall Experiments. D. L. DOUGLAS AND F. C. ZYSES. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-1376, November 1, 1955, 93 pp.

A new method of measuring the corrosion rate of metals in high-temperature water was developed. The method involves determining the amount of hydrogen evolved in the reaction. Corrosion measurements are carried out in small autoclaves, the gas space of which is filled with a known amount of a carrier gas, helium. After corrosion, a sample of the gas is taken, and is analyzed on the mass spectrometer. From the analysis and the amount of gas the hydrogen evolved in the corrosion reaction is readily calculated. Using this method, extensive measurements were made of the corrosion of Armco iron and high-purity iron over the temperature range 240 to 360°C. The effects of surface finish, temperature and heat-treatment were studied. In addition, measurements were made in saturated vapor, superheated vapor and certain dilute aqueous solutions. Electrolytically or chemically polished surfaces corrode at a rate that is very low compared with the rougher pickled surfaces. At 240°C the corrosion rate is low and constant with time. At 316°C and 360°C the corrosion behavior is best described by the cubic law, $m = k_1(t + k_2)^{1/2} + k_3$, where m is the amount of hydrogen evolved, t is the time, and k_1 , k_2 and k_3 are constants. An unexplained spread in the data prevented the determination of the constants, but the total corrosion for electropolished specimens ranged from about 0.5 to 1.0 millimoles of hydrogen evolved per square decimeter in 500 hours. No significant difference between Armco iron and the high purity iron was found. Also, no effect of temperature in the range 316 to 360°C was detected. Corrosion behavior is the same in saturated vapor, superheated vapor and the dilute solutions. Annealing the iron for a few hours at 800°C in hydrogen or a vacuum somewhat increased the corrosion rate. These results are discussed in terms of a mechanism involving diffusion of iron ions through a magnetite film. At 240°C the rate-determining step is postulated to be a Schikorr-type reaction, $3\text{Fe}(\text{OH})_2 \rightarrow \text{Fe}_3\text{O}_4 + \text{H}_2 + 2\text{H}_2\text{O}$. At the higher temperatures iron ion diffusion is likely to be rate-determining. Kirkendall-type experiments were carried out in order to identify the ion species diffusing through the magnetite film formed on corrosion of iron in high temperature water. (auth).—NSA. 11486

4.6.2, 7.6.4, 1.6

Treatment of Water for Marine Boilers. Draft British Standard (Revision of B.S. 1170), British Standards Institution, Subcommittee CHE/37/3 (Methods of Boiler Water Treatment) of Technical Committee CHE/37 (Boiler Water Tests) February, 1956, 59 pp.

The standard covers treatment of water for marine boilers with drum pressure up to 950 psi. It is designed to permit the engineer to control boiler water treatment under normal working conditions and describes three basic methods of chemical treatment from which a choice can be made according to the type of makeup feed in use. In all cases one or more alkaline reagents are used with or without an organic coagulant.

Extensive recommendations are made covering operation of condensers, treatment of makeup feed, oil contamination, oxygen in feed water, treatment of internal boiler surface after manufacture or repair, care of boilers not in service, scale formation, characteristics of different kinds of water, recommended chemicals, treatment methods, type and frequency of water tests and other matters. 11359

4.6.10, 2.3.4, 5.8.2

Inhibiting Corrosion of Steel, Aluminum and Magnesium Intermittently Exposed to Brines. GEORGE E. BEST AND JOHN MCGREW. *Corrosion*, 12, No. 6, 286t-292t (1956) June.

Prevention of corrosion of metals under continuous exposure to sodium or calcium chloride refrigerating brine is one of the earliest commercial applications of a chemical inhibitor. Yet comparatively little has been published about the effectiveness of inhibitors under conditions of discontinuous exposure.

An experimental technique designed only to provide comparative data and indicate orders of magnitude rather than precisely determined corrosion rates is used. Experiments establish that chromate effectively minimizes brine corrosion of mild steel and selected aluminum and magnesium alloys intermittently exposed to brines at ordinary temperatures. The importance of ratio between metal surface area and test solution volume is brought out, as is also the effect of pH through comparison of chromate with bichromate. Roughly—quantitative indications of inhibitor consumption are reported. 11387

4.7 Molten Metals and Fused Compounds

4.7

The Mechanism of Embrittlement by a Liquid Phase. R. EBORALL AND P. GREGORY. *J. Inst. Metals*, 84, Pt. 4, 88-90 (1955) Dec.

Liquid lead causes considerable embrittlement, with grain boundary failures, both in β -brass and in tin bronze, although it does not spread round the boundaries in the absence of stress. Failure is accompanied by spreading of the liquid lead along the cracks. The stress needed to make a given crack grow depends upon the surface energy required and this may be greatly reduced if the tip of the crack is filled with the liquid phase.—INCO. 11479

4.7, 3.6.5, 2.3.5

On the Electrochemical Series of Metals in Fused Alkali Fluorides. (In French.) KAI GRJOTHEIM. *Rapports Presentes au Congres International de l'Aluminium*, Paris, June, 1954, Vol. I, 1955, 131-136. Available from: R. Blanchard, 61 rue de la Tombe-Issoire, Paris.

The present investigation deals with an experimental determination at 850°C of the relative position in the electrochemical series of aluminum, manganese, chromium and nickel dissolved in the fused eutectic mixture of sodium and potassium fluorides. The experiments were of a preliminary character. Their purpose was to obtain information about the possibility of using Daniell-type cells for electrochemical measurements in fluoride melts when the diffusion potential of the liquid junction was neglected. The attempt seems promising and the method may be extended to other systems. (auth).—NSA. 11091

4.7, 6.3.10, 2.3.4

Reaction of Nickel in Molten Sodium Hydroxide. ROBERT S. PEOPLES, PAUL D.

MILLER AND H. DALE HANNAN. Battelle Memorial Inst. U. S. Atomic Energy Commission Pubn., BMI-1041, September 27, 1955, 13 pp.

The final experimental results are presented from a study of several phases of the nickel-sodium hydroxide system. It was shown that sodium oxide is a product of the reaction of nickel and sodium hydroxide at 950°C under either an argon or a hydrogen atmosphere. A discussion of the role of sodium oxide in the corrosion mechanism is given. A more detailed study of the nickel-sodium hydroxide system at 950°C under argon confirms the cyclic corrosion process suggested previously. A study of this system at 816°C has shown that at this lower temperature the corrosion is approximately half as severe as at 950°C for a given time interval. Details of the reduction procedure used for analysis of the residues are given. The results of these reductions have not provided a reasonable formula for the needlelike crystals found in the leached residues. (auth).—NSA. 11431

4.7, 8.4.5

Structural Materials for Heat Transfer in Nuclear Reactors. Part I. Selecting Materials for Liquid Sodium Systems. R. F. KOENIG AND E. G. BRUSH. *Gen. Elect. Co. Materials & Methods*, 42, No. 6, 110-114 (1955) Dec.

Problems encountered in using liquid sodium as a heat transfer agent for nuclear energy reactors, covering corrosion resistance of various structural materials, effects of oxygen, carbon and cover gases (helium, argon and nitrogen) as impurities in sodium, effects of sodium on brazed and welded joints, mass transfer, mechanical effects (galling and diffusion bonding) and transfer of radioactivity. Ferrous metals, superalloys, refractory metals, ceramics and cermets are discussed and corrosion data is presented for chromium-molybdenum steels, 12% chromium steel, Type 304, 310 and 347, Inconel X, Hastelloy X, A-286, 18% chromium-35% nickel alloy, among others. Tables, graphs, photomicrographs.—INCO. 11449

5. PREVENTIVE MEASURES

5.1 General

5.1, 1.7.3

A Practical Corrosion Service Program. B. J. PHILIBERT. *Corrosion*, 12, No. 4, 174t-176t (1956) April.

A corrosion engineer's work is both corrective and preventive. Doing better preventive work lessens corrective work required. A wide knowledge of materials and fabrication with good specifications to cover both is required of the corrosion engineer. Frequently a corrective corrosion or metals problem is the heart of an engineering problem. When a specific problem is isolated, the engineering problem usually must be solved before the materials problem. A simple substitution of materials of construction is frequently inadequate. By the accumulation and distribution of helpful preventive information, the corrosion engineer establishes his value as a consultant and recognition of his worth follows. 11221

5.2 Cathodic Protection

5.2.1

Cathodic Corrosion Protection. (In German.) R. RITTER. *Werkstoffe u. Korrosion*, 6, No. 11, 523-527 (1955) Nov.

Principles and applications of cathodic

protection are described. A method of measuring the potential of underground pipe lines and the effect of resistivity of the soil on the corrosion process is discussed. It is pointed out that the use of the cast alloy magnesium-6% aluminum-3% zinc, as a soluble anode, showed very good results. Where higher current densities are required, the so-called Galvoline, a special type of magnesium anode may be used. Galvoline is a flexible magnesium band with a cross section of 10 x 20 mm and reinforced with an iron core. The anode is unrolled from a reel carried by a truck which, at the same time, by means of a plough-like device, buries it in the ground. The amount of current thus obtainable is said to be 300 amp. hr. per m. —ALL. 11499

52.1
Economic Cathodic Protection. BENSON G. BRAND. *Corrosion Technology*, 3, 12-14 (1956) January.

The use of organic coatings in conjunction with cathodic protection is presented as an effective and economical method of preventing corrosion. Photograph.—BTR. 11332

52.1, 7.2
Problem of the Protection of Methane Pipes Against Electrolytic Corrosion. Parts I, II, III. (In Italian.) G. BIANCHI. *Riv. combustibili*, 9, Nos. 8/9, 10, 675-711, 789-824 (1955) August-September, October.

Thermodynamic and kinetics aspects; passive and active protection; electrical and electrochemical cathodic protection. Evaluates the effective protection of an underground structure. Grounding measurements as a criterion of protection. Diagrams, graphs, table.—BTR. 11309

52.1, 8.9.5
Navy Experimental Work with Cathodic Protection. IRVING D. GESSOW. *Corrosion*, 12, No. 3, 100t-106t (1956) March.

An account is given of work done by the Navy Bureau of Ships with cathodic protection of active and reserve ships. Because it is difficult to dissociate costs for maintenance and corrosion protection it is impossible to say whether or not the cost of cathodic protection of active ships is merited. Because corrosion damage to hulls seldom is considered except when perforations occur, or in destroyers and submarines where plates are thinner and original dimensions more critical, there is some belief that cathodic protection for all ships cannot be justified on a cost basis.

With inactive ships, however, the reverse is true. Indefinite extension of drydocking times, the interval contingent on the exhaustion of anti-fouling paints, is anticipated. Initial cost of cathodic protection of active destroyers, submarines and five types of reserve ships is tabulated. Details of cathodic protection systems for reserve ships are given. Criteria of protection differ somewhat from the accepted standards. In polluted waters inactive ships may require a potential in excess of 1 volt, while in other high resistivity waters 0.85 to 0.95 volts are sufficient. Some data are given on the cathodic protection of active ships. Merits of sacrificial anodes versus impressed current are listed. Extensive further activity in cathodically protecting active ships is contingent on the outcome of trials now under way. 11195

52.1, 8.9.5
The Cathodic Protection of Ships Against Sea-Water Corrosion. J. Am.

Soc. Naval Engrs., 67, 1074-1087 (1955) Nov.

Application of cathodic protection to the under-water surface of ships' hulls. Graph, diagrams.—BTR. 11364

5.2.3
Corrosion Mitigation in a Metropolitan Area. M. C. MILLER. *Corrosion*, 12, No. 5, 247t-253t (1956) May.

The corrosion mitigation of cable sheaths and other underground metallic structures in a metropolitan area involves many problems not encountered in the protection of cross-country cables and pipe lines. It is difficult for any one operator to apply protection to small section of his system or the entire system without increasing corrosion on other systems in the same area.

A description is given of how Miami utility companies participated jointly in the designing and installation of a cathodic protection system. Purpose of the project was to provide protection to all metallic structures in a certain downtown area. Eleven 50-ampere rectifiers were installed at selected locations throughout the area.

The selecting of reference electrode locations is discussed in detail. Other topics considered include cathodic protection design factors, tests made to determine need for resistance bonds, changes in construction practice, use of magnesium anodes and cost of installing cathodic protection.

After eight years' time the Miami cooperative corrosion control program was found to have provided good protection to electric and gas and communication systems. Corrosion failures on protected communication system cables were found to be almost nonexistent. Corrosion failures on electric cable sheaths were found to have dropped to one per year. 11337

5.2.3, 3.6.9, 7.7
A Method of Protecting Pipe Type Cables: Topic of the Month. F. E. KULMAN. *Corrosion*, 11, No. 11, 459t-460t (1955) Nov.

To overcome unwanted stray current, a 0.004-ohm resistor capable of carrying cable fault current is connected between pipe and station ground. Resistor consists of two stainless steel bars connected in parallel, formed into shape of a "W" for compactness. A 100-ampere rectifier is connected across resistor to maintain pipe end at 0.4 volt negative potential with respect to station ground. Arrangement requires little maintenance and is cheaper than method using batteries.—INCO. 11427

5.2.3, 7.10
Integration of Corrosion Control in Pier Substructures. CARL R. JOHNSON. *Corrosion*, 12, No. 4, 157t-160t (1956) April.

Integration of cathodic protection in design of three piers in New York Harbor is described. All are constructed of steel H-piling driven to rock. Rectifiers were selected in lieu of galvanic anodes and a provision was made to locate controls for all circuits in an alarm panel. When any circuit drops below 50 amperes, the circuit light goes out and an alarm bell rings. Details of installation, criteria of protection and other details of tests, surveys and installation are given. Test or control piles have been driven to make possible a check on the effectiveness of the protection. 11119

5.3 Metallic Coatings

5.3.1
Zinc Coatings for Protecting Steel.

E. W. HORVICK. *Am. Zinc Inst. Product Eng.*, 26, No. 13, 158-161 (1955) Dec.

Discusses the electrochemical advantages of zinc coatings as corrosion protection for steel, methods of applying zinc coatings—hot-dip and continuous galvanizing, electrodeposition, metallizing (spraying) and Sherardizing and coating thickness specifications.—INCO. 10812

5.3.1, 5.4.1, 5.9.1, 1.6
Industrial Finishing Year Book, 1955. W. F. COXON, Editor. Book, 439 pp. Published by Arrow Press Ltd., 157 Hagden Lane, Watford, Herts. (Free to subscribers to *Industrial Finishing*).

This sixth edition is much the same as the 1954 Year Book and covers cleaning, polishing, electroplating, metal coloring, paints, plastics, standard specifications, sources of supply, etc.—BNF. 10458

5.3.1, 5.4.1, 5.9.4
Finishes for Metal Products. Materials & Methods, 42, No. 9, 117-132 (1955) September.

Outlines briefly the types of permanent finishes applied to metal products and covers conversion coatings: phosphate, chromate, various oxides for color effects and anodic coatings; organic coatings: oil paints, varnishes and enamels (phenolics, alkyds, epoxy, silicone, furane, Neoprene, resin coatings), lacquers (nitrocellulose, vinyl, acrylic, rubber derivatives), dispersions and emulsions (phenolic, fluorocarbon, latices) and hot-melt, clad and impregnated organic coatings; metallic coatings: electroplated (including nickel, copper, chromium, rhodium, platinum, palladium), immersion (nickel, tin), hot dip (tin, zinc, lead-tin, aluminum), sprayed (zinc, aluminum, molybdenum, wear re-

**Protect Pipe & Coating
against ROCK!**

WITH

**KAPCO
ROCK SHIELD**

**No dirt-padding needed!
Saves Man-Hours &
Equipment in Backfilling**

Kapco — a tough, mastic composition board, widely used for external protection for pipe in rocky areas, during handling and backfilling . . . easily installed . . . combats corrosion.

**MIDWESTERN
PIPE LINE PRODUCTS CO.**
Box 1886 Tulsa, Oklahoma

sistant alloys such as stainless, Monel, nickel), vapor deposited (evaporated and cathode sputtered), diffusion (Sherardized, chromized, calorized, siliconized) and fused coatings (hard facing); and inorganic coatings: porcelain enamels and ceramics. INCO. 10889

5.3.1, 6.3.14

Proceedings of the Symposium on Tin as Corrosion Resistant Material. (In Italian.) CONSIGLIO NAZIONALE DELLE RICERCHE. *Metallurgia Italiana*, 47, No. 5, 197-225 (1955) May.

Papers presented were: The Simultaneous Electrodeposition of Two Metals with Special Reference to Tin Alloys, E. S. Hedges (pp. 197-199); Researches on the Electrochemical Behavior of Tin, Part I, R. Piontelli, G. Serravalle and R. Ambrosetti (pp. 200-203); Considerations on the Electrodeposition of Alloys, R. Piontelli (pp. 204-209); Comparison of the Fields of Application of Electrolytic and Hot Dip Tinplate, W. R. Lewis (pp. 210-215); Research on the Corrosion of Tin and Its Protective Action on Iron, G. Bianchi (pp. 216-219); Some Observations on the Appraisal of the Corrosion Behavior of Tinplate, W. E. Hoare (pp. 220-221); Polarographic and Colorimetric Determination of Tin and Iron in the Study of Tinplate Corrosion, L. Felloni (pp. 222-223).—BNF. 10563

5.3.2

A Survey of Metallurgical Films. J. P. MOORE. *Metallurgia*, 51, No. 308, 267-277 (1955) June.

Gives list of suppliers and classifies films with short comments on each film under the headings: properties, structure, examination and testing of metals and alloys; corrosion and protection; foundry practice; extraction of non-ferrous metals; iron and steel making; metal working and welding; heat treatment; miscellaneous.—BNF. 10606

5.3.2

Zinc Coatings on Steel. R. W. BAILEY. *Ind. Finishing* (Brit.), 8, 401+6 pages (1955) July.

Describes the history and characteristics of varying types of zinc coatings and gives details of exposure test work on them. Micrographs, graphs, photographs, tables, diagrams, 8 references.—BTR. 10480

5.3.2

Cladding of Steel and Concrete with Corrosion-Resisting Sheet Material. (In German.) P. VOIGT. *Werkstoffe und Korrosion*, 6, No. 7, 337-343 (1955) July.

Report on development and long-time tests of a new method of protecting equipment, vats, tanks, etc., made of concrete, steel or masonry, against corrosion, using highly-alloyed thin sheet metal, 0.6 mm. thick. The cladding materials are 18/8 Mo or straight 18/8. Some details of applications are given.—INCO. 10340

5.3.2

Recent Applications of the Corrosion-Protective Metal Spraying in Austria. (In German.) H. REININGER AND R. RENGSHAUSEN. *Metall*, 9, No. 11/12, 487-488 (1955) June.

The anti-corrosive properties of aluminum and zinc coatings applied by spraying are discussed. Some recent works in this field, including the aluminizing of steel milk tanks in Austria, are described. Photographs, 12 references.—ALL. 10626

5.3.2

Conference on Structure and Properties of Electrodeposits. Birmingham

University Dept. of Industrial Metallurgy *Metal Ind.*, 86, Nos. 13, 14, 15, 16, 247-250, 273-275, 295-296, 311-313 (1955) April 1, April 8, April 15, April 22.

Papers by R. A. F. Hammond (April 1 issue), Properties and Engineering Applications of Electrodeposits (adhesion, hardness, tensile properties, effect on fatigue properties), and D. N. Lanyon (April 8), The Crystal Structure and Properties of Electrodeposited Metals (surface roughness and color, hardness, ductility, stress, conductivity and porosity are related to crystal orientation and size, lattice structure and crystal habit or shape). Extracts from the discussion (April 15) of the above papers. April 22 issue contains paper by J. W. Cuthbertson, Electrodeposited Alloys (plating with tin-zinc, copper-tin and tin-nickel, very brief reference to tin-cadmium).—BNF. 10649

5.3.2

Corrosion-Resistance of Electrodeposited Alloys of Tin. P. DEHAIS. *Metaux, Corrosion-Industries*, 30, 185-191 (1955) May.

Report of atmospheric and salt-spray exposure tests on nickel-tin and tin-zinc electrodeposits, with comparative data on nickel plus chromium systems.—INCO. 10742

5.3.2

The Properties and Engineering Applications of Electrodeposits. R. A. F. HAMMOND. *Metal Finishing J.*, 1, Nos. 5, 6, 193-195, 198; 259-262 (1955) May, June.

Discusses electrodeposition of heavy nickel coatings for repair of worn parts and hard chromium for wear resistance. Adhesion and mechanical properties of electrodeposits, effect of electrodeposited coatings on the mechanical properties of steel; possible methods of overcoming reduction in fatigue strength due to electrodeposited coatings.—BNF. 10780

5.3.2

Tin-Zinc Alloy Plating; Its Application to Copper Wire. F. A. LOWENHEIM AND R. T. GORE. Paper before Wire Assoc., Ann. Conv., Chicago, November 14-17, 1955. *Wire & Wire Products*, 30, No. 10, 1219-1221, 1295-1297 (1955) October.

Tin-zinc alloy (78 percent tin) possesses advantages over pure tin in retention of solderability, corrosion resistance and freedom from phase transformation known as tin pest. Copper panels coated with .0035-inch of tin and tin-zinc and exposed to severe marine atmosphere indicated superior corrosion resistance of the alloy. Solderability is retained almost indefinitely under normal storage conditions. Pure electrodeposited tin undergoes a phase transformation in four days in a cold cabinet at -100 F, whether inoculated with gray tin or not, while tin-zinc shows no transformation for two years when not inoculated and for seven months when inoculated. Alloy plating process and bath composition are presented.—INCO. 10861

5.3.2

Structure and Thermal Treatment of Zinc Coatings. (In German.) W. KATZ. *Metall*, 9, No. 15/16, 652-655 (1955) August.

In atmospheric corrosion of zinc coatings, the uniform thickness of zinc is the decisive factor. Attack is general. In water, local attack occurs, the layered structure by the alloy phases of the iron-zinc system playing a part. In the atmosphere, the alloy layers highest in iron are most resistant. Author investigates production of

such layers by heat-treatment of hot-dipped coatings. Various iron-zinc phases additional to those occurring in the hot-dipping process are thus obtained.—BNF. 10798

5.3.2

Electron Microscope Studies on Copper Deposits from Sulfate and Cyanide Baths. S. OKADA AND S. MAGARI. Paper before Electrochem. Soc., Pittsburgh, Oct. 9-13, 1955. *J. Electrochem. Soc.*, 102, No. 10, 580-585 (1955) October.

Copper deposits from sulfate and cyanide baths, at low current densities, show lack of uniformity on various cathodes. Crystal structure of base metal has a profound influence on nonuniformity, which is characteristic for a given single crystal cathode, but differs markedly for the two different electrolytes. Planes parallel to (010) and (111) planes of the base crystal develop in a copper sulfate bath while, in a cyanide bath, planes develop parallel to the (130) plane of the base crystal.—INCO. 10837

5.3.2, 2.2.2

How Zinc Coatings Slow Atmospheric Corrosion. O. B. ELLIS. *Armco Steel Corp. Iron Age*, 176, No. 7, 79-81 (1955) August 18.

Long term exposures of zinc-coated sheet specimens reveal their behavior under different conditions of atmospheric corrosion. Exposure sites included New York, Kure Beach, N. C., Sandy Hook, N. J., and Middletown, Ohio. New York's atmosphere was most severe (more so in fall than in spring). Specimens continuously exposed show that zinc corrodes proportionately to time in mild industrial atmosphere but decreases with time in marine atmosphere. Continuous coating methods without flux permit use of aluminum in zinc bath which suppresses formation of brittle iron-zinc alloy and reduces incidence of white rusting. Change in color of corrosion products as corrosion progresses from white zinc rust to zinc-iron alloy and finally to base metal, is discussed. Graphs, photomicrographs.—INCO. 10788

5.3.2, 3.5.8

Stress During the Electrodeposition of Copper on Copper Substrate. H. SADEK, M. HALFAWY AND S. G. ABDU. *J. Electrochem. Soc.*, 102, No. 5, 226-228 (1955) May.

Strips of electrolytic copper, 0.3 mm thick, were coated with a mixture of wax and petroleum jelly on one side and the deflection they suffered during electrodeposition was measured. The observed stress (tensile) was greatest in deposits produced at 2 amp./dm.² An acid copper sulfate bath was used throughout.—BNF. 10390

5.3.2, 3.6.3

Conductivity Measurements on Electrodeposited Metal Foils. A. KEIL. *Metall-oberfläche, Ser. A*, 9, No. 6, 81A-84A (1955) June.

Measurements on gold, silver and rhodium, with an eddy current testing apparatus, to compare conductivity of electrodeposited foil parallel to its surface (which is of importance for high frequency technique) with that of massive metal. In all cases it was lower. There is special discussion of the case of rhodium.—BNF. 10548

5.3.2, 3.8.2

Electrochemical Principles of Metallic Coatings, Part I. Electrochemical Principles of Corrosion. Part II. Mechanism of Protective Action of Metallic Coat-

hot-dipped
ases addi-
ne hot-dip-
ed.—BNF.
10798

s on Cop-
d Cyanide
ARI. Paper
burgh, Oct.
, 102, No.

and cyanide
show lack
es. Crystal
profound
which is
gle crystal
or the two
parallel to
ase crystal
h while, in
parallel to
crystal—
10837

atmospheric
mco Steel
-81 (1955)

zinc-coated
avior under
pheric cor-
New York,
ook, N. J.,
rk's atmos-
so in fall
continuously
es propor-
rial atmos-
in marine
g methods
uminum in
rmation of
es incidence
lor of cor-
progresses
-iron alloy
discussed.
CO. 10788

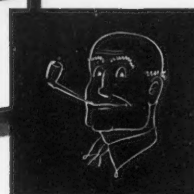
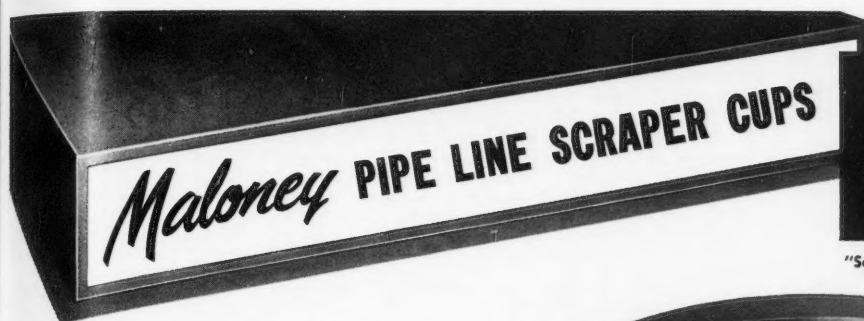
position of
H. SAEK,
J. Electro-
28 (1955)

r, 0.3 mm
ure of wax
le and the
g electro-
e observed
in deposits
acid copper
oughout.—
10390

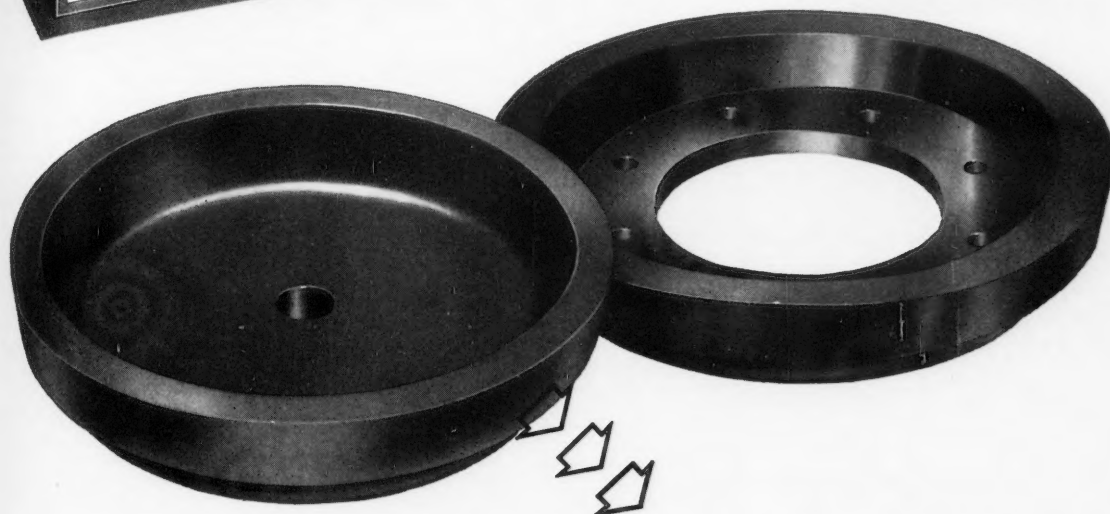
on Elec-
EEL. Metal-
81A-84A

ilver and
ent testing
activity of
to its sur-
e for high
at of mas-
was lower.
the case of
10548

of Metallic
nical Prin-
Mechanism
allic Coat-



"Something from the Irishman"



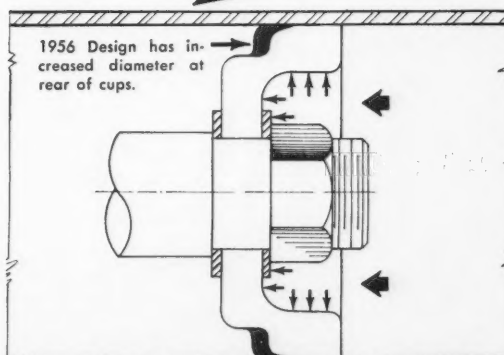
The NEW, IMPROVED DESIGN

of Maloney scraper cups
assures long life and even wear

Service has proved the cup ideal for "out of round" and varying weight pipe due to the flexibility and parallel faces of the cup lip. Flexibility is accomplished by the design at the back of the cup, which permits the wiping surface to expand or contract and follow the pipe contour.

The parallel faces of the lip give longer life to the cup and maintain the effective length of the wiping surface, regardless of wear. The parallel faces also give uniform pressure. Competitive cups having a sharp edge do not wear evenly and as wear takes place, the length of the wiping surface decreases.

Maloney scraper cups are manufactured from a selected Neoprene compound, have excellent abrasive qualities, proper flexibility and retain dimensional stability under all service conditions. The Maloney 1956 design has increased the diameter at rear of cups.



F. H. MALONEY
Houston, Texas *Company*

**Since 1932—Precision In
Rubber—Metal—Plastics**

2301 TEXAS AVE. • FAirfax 3-3161
HOUSTON • LOS ANGELES • TULSA

GALVANIZE

after Fabrication



Welding, cutting, shearing, punching, etc., leave exposed surfaces where rust has a chance to begin. If this work is done before Hot-Dip Galvanizing there will be no exposed surfaces. That's why we say—have your products Hot-Dip Galvanized after fabrication and there will never be a weak spot in your finished product.

Members of the American Hot-Dip Galvanizers Association have the know-how to do a top quality job. Write today for a list of our members and our STOP RUST booklet.



**Send for
Free
Booklet**

American Hot-Dip Galvanizers Association, Inc.
1806 1st National Bank Bldg., Pittsburgh 22, Pa.

Name _____
Firm _____
City _____ State _____



ings. Part III. Corrosion at Pores and Discontinuity in Metallic Coatings. L. L. SHREIR. *Ind. Finishing*, 8, 261+4 pages; 326+4 pages; 389-392, 394, 400 (1955) May, June, July.

Dry and wet corrosion; potentials of corroded metals; electrochemical cells. Polarization and its effect on protection; factors of corrosion potentials; anodic and cathodic coatings; evaluation of porosity tests. Graphs, tables, diagrams, micrographs. 59 references.—BTR. 10395

5.3.2, 4.3.3

The Effects of Repeated Washing of Tinned Steel with Alkaline Solutions on Its Resistance to Rusting. S. C. BRITTON AND D. G. MICHAEL. *J. Applied Chem.*, 5, 402-414 (1955) August.

Rate of corrosion of specimens either intermittently or continuously immersed in equivalent caustic alkalinity solutions of sodium hydroxide, carbonate, or phosphate with additions of either sodium sulfate, chromate, or hypochlorite. Tables, photographs. 8 references.—BTR. 10680

5.3.2, 5.4.5, 7.7

Selection Factors for Heavy-Duty Finishes. R. E. HARR AND D. J. MANNING. *Western Elec. Co., Inc. Elec. Mfg.*, 55, No. 2, 108-112 (1955) February.

Finishes for telephone equipment fall into three classes: organic, hot galvanized and electroplated. Electroplated finishes are applied for protection against corrosion, for good mechanical wearing qualities, to improve solderability and to reduce electrical surface resistivity. Telephone relays are plated with nickel and chromium to provide good wearing qualities. Nickel undercoating for relay cores and armatures is dull and relatively soft since it is plated from standard Watts-type nickel solution. Bright nickel finishes have been considered but advantages of a harder nickel base do not warrant additional cost of brightening agents and added control effort.—INCO. 10387

5.3.2, 5.4.5, 5.2.2

Metallic Zinc as Protection Against Corrosion. (In German.) R. HAARMANN. *Metall*, 9, No. 15/16, 646-648 (1955) August.

Explains hydrogen and oxygen types of corrosion and the protection of iron against corrosion by galvanizing, electrolytic zinc plating, zinc spraying, diffusion of zinc into the iron surface, application of paints or pastes with pigment of metallic zinc dust and cathodic protection with zinc. Tables, 14 references.—MR. 10412

5.3.2, 5.9.4, 2.3.7

Testing Coatings Produced Electrochemically. (In German.) J. ELZE. *Metall*, 9, No. 11/12, 458-465 (1955) June.

After listing important mechanical, physical and chemical properties of such coatings, discusses metallic coatings (thickness, roughness and gloss, porosity, hardness, internal stress, impurities, electrical properties); anodic coatings on aluminum and wrought aluminum alloys (coarse pores, thickness, general porosity).—BNF. 10827

5.3.2, 6.4.2, 1.2.5

Aluminium-Water Hazards. W. Y. CHEN AND S. L. GOLDHEIM. *Ind. and Eng. Chem.*, 47, No. 7, 32A, 34A (1955) July.

In certain circumstances mixtures of aluminum dust and water will suddenly heat up and evolve hydrogen, par-

ticularly if iron filings are present. Sprayed aluminum coatings were also found to react with water with evolution of hydrogen.—BNF. 10866

5.3.2, 7.2

Aldip Coating Improves Valves Durability. R. F. THOMSON, D. K. HANINK, E. B. ETCHHELLS AND K. B. VALENTINE. *SAE Journal*, 63, No. 8, 54-56 (1955) August.

General Motors' Aldip process provides a smooth, thin coating of aluminum on engine intake valves without destroying the valve, if it is stress-relief annealed or relatively free from straightening stresses. A year's production experience at Pontiac Motor Division indicates that the treatment is commercially feasible and very beneficial to valve life. The valves are Aldip processed after the seats have been finish machined and the stems rough ground. The process consists essentially of dipping about 1 inch of the head end of the valve into a molten flux bath, followed by dipping it into molten aluminum. The valve is then held in a fixture while compressed air removes the surplus molten aluminum. The flux is composed of 40 percent sodium chloride, 40 percent potassium chloride, 10 percent sodium aluminum fluoride and 10 percent aluminum fluoride, held at a temperature of 1325 F. Tests of valves in the laboratory and in the field indicate that the Aldip treatment will increase the durability of XB exhaust and GM 8440 intake valves by at least 100 percent under certain conditions. In a series of three tests, only two of nine Aldip coated valves failed, whereas nine original and eight replacement uncoated valves burned and failed. Field tests using four Aldip-coated valves and four uncoated valves in a heavy-duty, 2-ton truck engine showed that all four uncoated valves "burned" and none of the Aldip-coated valves failed. Eighteen test cars, 10 having engines equipped with Aldip-treated valves and eight having engines equipped with plain valves, were operated under accelerated test conditions for various mileages up to 51,040 miles.—ALL. 10368

5.3.3

Sprayed Metal Coatings. Part I. Protection of Iron and Steel Against Atmospheric Corrosion. Part II. Protection of Iron and Steel by Aluminium Against Corrosion at Temperatures Between 120 C and 950 C. British Standard 2569: Parts 1 and 2, 1955, 7 pp. each. British Standards Institution, 2 Park Street, London, W. 1.

Part I. Spraying of aluminum or zinc by molten metal, powder or wire pistol: surface preparation, sieve analysis of powder, thickness and adhesion test. Part II. Spraying with aluminum and aluminum alloy by powder or wire pistol: surface preparation, metal composition, sieve analysis of powder, processing treatment after application and thickness. A summary of the Standard and comparison with the Recommended Practice of the American Welding Society is given in *Electroplating*, 8, No. 5, 177-180 (1955) May.—BNF. 10479

5.3.3

The Protection of Iron and Steel by Sprayed Coatings of Aluminium or Zinc. F. A. CHAMPION. *Electroplating and Metal Finishing*, 8, No. 5, 180-182, 189 (1955) May.

The British Standards Institution has recently published the first two parts of

present.
were also
evolution
10866

alves Dur-
HANINK,
VALENTINE,
56 (1955)

process pro-
of alumi-
without det-
stress-relief
free from
's produc-
Motor Di-
treatment is
very bene-
are Aldip
have been
mis rough
essentially
head end
bath, fol-
ten alumi-
a fixture
s the sur-
ix is com-
chloride, 40
0 percent
d 10 per-
at a tem-
valves in
d indicate
l increase
and GM
t 100 per-
In a series
line Aldip
nine orig-
uncoated
field tests
s and four
uty, 2-ton
four un-
one of the
hiteen test
oped with
nt having
lves, were
st condi-
to 51,040
10368

rt I. Pro-
st Atmos-
tection of
n Against
etween 120
ard 2569;
h. British
k Street,

m or zinc
ire pistol:
alysis of
sion test,
num and
or wire
etal com-
der, proc-
ation and
Standard
mended
lding So-
8, No. 5,
10479

Steel by
n or Zinc
and Metal
89 (1955)

ution has
o parts of

a new British Standard (B.S. 2569/1955) dealing with sprayed metal coatings. Part One provides for the Protection of Iron and Steel Against Atmospheric Corrosion, while Part Two provides for Protection of Iron and Steel by Aluminium Against Corrosion at Temperatures Between 120 and 950 C. This article is a commentary on the recent British Standard. Although tests over a ten-year period have shown that the required coating thickness was only three mils for aluminum compared with five mils for zinc, this British Standard specifies minimum thicknesses in the reverse order, namely four mils for aluminum and three for zinc. This relative increase in the thickness of the aluminum coating is required to guard against deterioration of appearance which sometimes occurs during the initial stages of exposure.—ALL. 10457

533, 53.4

Recommended Practices for Metallizing: Part 1D. Metallizing Flat Surfaces. Brochure, 1955, 16 pp. The American Welding Society, 33 West 39th Street, New York 18, New York.

This is the fourth in a series of AWS reports on metallizing. Included are surface preparation, covering cleaning; undercut, bonding coatings, grooving, groove and rotary roughing tool method, groove and knurling method and studding. Spraying equipment and materials are detailed with formulae and tables for weight, spraying procedure, causes and prevention of cracking, physical properties of sprayed metals and finishing. 10464

53.4

Electrodeposition of Rhodium. E. A. PARKER. *Technic, Inc. Plating*, 42, No. 7, 882-892 (1955) July.

Factors affecting the deposition of rhodium 0.000001-0.001 inch thick were studied. The simple sulfate concentrate plus sulfuric acid gave the best overall results with respect to increased current efficiency, brightness and smoothness of plate and less sensitivity to additions of other salts and impurities. Added metallic impurities, nickel, copper, cadmium, lead, silver and tin, with exception of nickel produced harmful effects in concentrations less than 35 milligrams per gallon. Addition of EDTA to the contaminated solutions even at 0.5 pH had some beneficial effects. Methods of purification are discussed. Applications which depend on decorative white finish, hardness, corrosion resistance, optical reflectivity, low electrical resistance and combinations are described.—INCO. 10591

53.4

The Effect of Aluminium Additions to an Experimental Hot-Dip Galvanizing Bath on the Rate of Attack on Steel. N. B. RUTHERFORD. *Metal Finishing J.*, 1, No. 6, 276-277 (1955) June.

It is concluded that for shorter immersion times the rate of attack increases parabolically with time, both with and without aluminum additions, (attack is about 13 percent greater for 0.1 percent aluminum); for longer immersion times the rate increases more rapidly, coatings are rough, sometimes cracked or flaked. Rate of attack is the same for pickled or pregalvanized specimens. The scale present on the steel due to processing provides some measure of protection at immersion times up to 32 hours but has no effect at 120 hours. The information in this paper is

taken from report RRA 884 made available to British Non-Ferrous Metals Research Association members in July, 1950; reprints are available as RRA 1046P.—BNF. 10586

5.4 Non-Metallic Coatings and Paints

5.4.2

Protection of Low-Strategic Alloys with a Chromium-Boron-Nickel Cermet Coating. D. G. MOORE AND J. R. CUTHILL. Paper before Am. Ceramic Soc., 56th Ann. Mtg., Enamel Div., Chicago, April 19-23, 1954. *Bull. Am. Ceram. Soc.*, 34, No. 11, 375-382 (1955) November.

Describes new procedure for depositing a chromium-boron-nickel layer on metal or alloy surface using standard ceramic coating technique. Coating slip is prepared by ball milling mixture of the cermet powder

with frit, clay and water and is applied by dipping or spraying. After drying, specimens are fired at 1900-2000F in combustion gas atmosphere. Cermet particles melt to form continuous layer (melting point of 1900F) which brazes to alloy surface. Thermal expansion, hardness and ductility of coating are discussed. Exploratory experiments were made on 18-gauge Inconel specimens. Heating tests on ingot iron and low-alloy steel (17-22-AS and Sicromo, compositions given) showed that cermet layers as thin as 0.002-inch provide oxidation protection for more than 800 hours at 1500F. Tables, photomicrographs.—INCO. 11441

5.4.2, 2.3.7, 3.5.6

Hydrogen Permeability of Steel and Its Relation to Enamellability. Y. LINDBLOM AND S. E. DAHLGREN. Paper before 2nd Internat. Enamelling Cong., Leamington

ARMED
Protective Coatings
Coal Tar Base Enamels

Reilly
COAL TAR PRODUCTS

REILLY TAR & CHEMICAL CORPORATION
Merchants Bank Building, Indianapolis 4, Indiana

Spa, October 1955. *Metal Finishing J.*, 1, No. 12, 517-524; disc., 524-526 (1955) Dec.

Investigates any possible relations between hydrogen permeability in steel, measured at 40°C and its gas content, metallographic structure and analysis and how this corresponds to enamelling results. Influence of pickling inhibitors, surface conditions and iron base on hydrogen diffusion is discussed. Apparatus and experimental data for determination of hydrogen adsorption by measuring hydrogen penetration by diffusion are reviewed. Adherence of enamel to sheet steel is expressed by adherence index, e.g. the percentage of deformed area still covered with enamel after deformation by hydraulic press. Tables, graphs.—INCO. 11425

5.4.3, 6.6.7, 6.6.8, 8.8.5

The Application of Rubber and Plastics to the Metal Finishing Industry. E. W. MULCAHY. *Bull. Inst. Met. Finishing* (Trans. IMF), 5, No. 3, 149-158 (1955) Autumn.

Rubber lining of tanks, including joining, surface preparation and high frequency spark test; applications of plastics (PVC and polythene) and reinforced resin plastics such as fibreglass.—BNF. 11420

5.4.5

Rust Inhibitors in Paints. J. PATTERSON. *Chim. Peintures*, 18, No. 9, 314, 316 (1955).

A brief discussion is given of the mechanism of action of corrosion inhibitive additives (diamines, benzoic acid derivatives, etc.).—RPI. 11432

5.4.5

Zinc Oxide and Corrosion Protection. A. FOULON. *Metal*, 9, No. 3/4, 123 (1955); *Chem. Abs.*, 49, No. 9, 66211 (1955).

Protective paints are improved if they contain metal soaps, such as lead or zinc soaps, which increase hardness, adhesive strength and elasticity. Of greatest value are basic pigments, particularly if they contain zinc oxide and basic lead sulfate, obtained by the vaporization of lead/zinc ores. In addition to providing physical protection, such pigments act in an electrochemical manner to passivate the metal surface. Such leaded zinc oxide has good covering power and gives high gloss, a smooth surface and fine zinc oxide particles, good durability.—RPI. 11411

5.4.5

Fluorocarbon Dispersion Coatings. GENE BARTZAK. *Materials & Methods*, 42, 90-95 (1955) Nov.

These coatings are finding acceptance in industry because of their unique chemical, physical and mechanical properties. Tables, photographs.—MR. 11286

5.4.5

Effect of Mica on the Embrittlement of Anticorrosive Primers for Steel. H. W. CHATFIELD. *Product Finishing*, 8, No. 10, 50-56 (1955) Oct.

The embrittlement of anticorrosive primers on ageing, as shown by the development of cracks which may be accompanied by flaking, can be reduced by the addition of water-ground mica to the primers, without affecting their anticorrosive properties. Some research that has demonstrated this function of mica in various types of primer is described.—RPI. 11379

5.4.5

Catalyzed Silicone Coatings. HAROLD L. CAHN. *Ind. Finishing*, 32, 42+5 pages (1956) Jan.

Mechanism of curing silicone resins.

Acceleration of the cure by catalysis. Diagrams, 5 references.—BTR. 11302

5.4.5

Phosphating Etch Primers. R. BOURBON AND J. J. M. DE PAULIN. *Metal Ind.*, 87, No. 21, 424-427 (1955) November 18.

Various phosphating primers (a vinyl resin/zinc chromate/phosphoric acid, freshly prepared or ready mixed) were tested on aluminum, Duralumin and aluminum-magnesium alloys. Those giving the best results were subjected to salt-spray tests, water at 35°C, moist heat at 70°C and exposure to weathering with and without top paint coats.—BNF. 11319

5.4.5

Strippable Stop-Off Coatings. M. C. BRYANT. *Plating*, 42, No. 10, 1273-1274 (1955) October.

Formulation; methods of applying; limitations of vinyl polymer stop-off films.—BNF. 11328

5.4.5

Tests on the Protection Given to Metals by Etch Primers. H. G. COLE. *Gt. Brit. Royal Aircraft Establishment, Technical Note Met. 209*, January, 1955, 13 pp.

Long-term (up to 4½ yr.) seawater-spray corrosion tests showed that the relative performance of paint systems based on six commercial wash primers varied markedly from metal to metal. The primers were self-neutralizing etch mixtures of phosphoric acid, polyvinyl butyral and zinc tetroxochromate. Five were of the two-solution type and one of the one-solution type.

On zinc- and cadmium-plated steel, the two wash primers tested gave better performance than did conventional paints applied over conventional surface pretreatments and are preferred, especially if the plating is not passivated. On unplated steel and on two aluminum alloys, the use of wash primers is an acceptable substitute for anodizing or phosphating, provided that the wash primer is followed by a full protective painting scheme. For best protection, anodizing of aluminum and phosphating of iron followed by an oil-type zinc chrome primer is recommended. On magnesium alloys the use of wash primers is risky because of the danger of attack on the metal through scratches in the chromate coating.—PDA. 11307

5.4.5, 1.6

Chemistry of Paints. (In French.) G. CHAMPETIER, H. RABATE AND J. L. RABATE, Editors. Vol. I, 1956, 662 pp.; Vol. II, 1956, 643 pp. Published by Dunod, 92 Boulevard St. Louis, Paris, France.

The volumes are essentially an encyclopedia of information on the scientific and technical achievements of the French painting industry. General information and specific developments in the industry during the past 20 years are discussed with the assistance of numerous specialists in the areas covered.

The chemistry and other interesting characteristics of materials used in paints, including molecular schemes, are included in diagrams and tables. Each chapter is referenced.

Diagrams and photographs of equipment, techniques and processes used in obtaining raw materials and producing paints and their constituents are covered. Characteristics of organic coloring materials and pigments are discussed; metallic and mineral pigments and solvents also are detailed. 11361

5.4.5, 1.7.1

Report on Application Techniques, Physical Properties and Chemical Resistance of Chlorinated Rubber Coatings. A Report of NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. R. MCFARLAND, JR. Chairman. *Corrosion*, 12, No. 4, 191t-195t (1956) April.

Chlorinated rubber can be formulated into coatings which exhibit excellent resistance to most acids, alkalis, salts, mineral oils, moisture and fungus growth. Resistance to oxidizing agents is generally good but is dependent on temperature and concentration of the oxidizing agents. Chlorinated rubber has excellent electrical properties and is nonflammable.

Recommendations are made regarding the use of chlorinated rubber coatings in various media. Corrosives in which tests were made include eight acids, water, five alkalies, six oxidizing agents, eight salt solutions, eight solvents, three fats and oils, chlorine, bromine, iodine, carbon dioxide, sulfur dioxide and hydrogen sulfide. Recommendations in these media are made both for a temperature of 120°F and for room temperature (70°F).

Physical properties of chlorinated rubber are given. Application of coatings is discussed in detail with attention given to coverage and shipping data, flammability and toxicity, surface preparation, priming and application methods. Properties of applied coatings and linings are considered with respect to temperature limitations, impact and abrasion resistance, hardness, aging, toxicity and odor, weight and electrical properties. 11111

5.4.5, 1.7.1

Report on Epoxy Resins. A Report of NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. R. MCFARLAND, JR., Chairman. *Corrosion*, 12, No. 4, 187t-190t (1956) April.

Baked epoxy resin finishes yield coatings which give maximum resistance to alkalies, solvents, most acids and general chemical fumes. With the air-dried system in which the epoxy resin is reacted with oil fatty acids to form an ester, the coatings have limited solvent and chemical resistance. The resistance to corrosion, however, is good. With the air-dried system in which the basic epoxy resin is dissolved in suitable solvents and blended with an amine, the coating does not develop full chemical resistance for several days. After this time it shows generally good resistance to chemical fumes, alkalies, acids and salt solutions.

Recommendations are made regarding the use of epoxy resins in various media. Corrosives in which tests were made include three concentrations of sulfuric acid, three concentrations of hydrochloric acid, two concentrations of nitric acid, two concentrations of phosphoric acid, glacial acetic acid, water, two concentrations of sodium hydroxide, ammonium hydroxide, oxidizing agents, three fats and oils, three gases, aldehydes, amines, eight solvents, five salts and four miscellaneous materials. Epoxy phenolic baked coatings, epoxy amine cured coatings and epoxy ester coatings are considered separately in connection with recommendations for use in the above media.

Application of epoxy resin coatings is considered briefly. Topics discussed include coverages, surface preparation, primers and application methods. Physical properties of epoxy resins are outlined briefly. 11198

drance of corrosion of metals by one or several substances, called corrosion-inhibitors, which are added to the corroding medium for this purpose or are already to some extent present in it; this definition excludes the hindering action of galvanic platings, anodic covering layers, etc. Physical (reversible) inhibitors are classified as adsorbable and polarizable. Chemical (irreversible) inhibitors are either passivators, which react with the metal surface to form a thin covering film, or destimulators, which destroy the activating action of a stimulator by reacting with it. Electrochemical (irreversible) inhibitors consist of ions or complex molecules of nobler metals, determined under the corrosion conditions, which enter into an electrochemical displacement reaction with the surface atoms of the metal to be protected and cause an excess of noble metal to

occur. Inhibitors may be further classified as ions, dipoles and molecules.—MA. 11391

5.8.1

Qualitative Analysis of Surface-Active Agents. V. W. REID, T. ALSTON AND B. W. YOUNG. *Analyst*, **80**, No. 954, 682-689 (1955).

A simple qualitative scheme has been developed for the characterization of surface-active agents. It is more positive than previous schemes. Present methods depend upon the application of a large number of chemical tests and this work shows how the number of such tests may be greatly reduced by the ultra-violet spectroscopic examination of the products. Reference compounds, similar in chemical structure to the various types of commercial product, have been examined in the ultra-violet region to provide data by means of which

classification of surface-active agents may be made. About 100 commercially available proprietary products have been examined by the scheme and the classification indicated agreed with data given in the literature for the products examined, when such data were available.—RPI. 11497

5.8.1, 2.3.8, 4.4.7

A Pilot Plant for Studying Corrosion Rates. W. R. POLLARD AND J. V. LAWSON. Paper before Am. Chem. Soc., 1st Oklahoma Tetra-sectional Mtg., Norman, April 16, 1955. *Ind. and Eng. Chem.*, **47**, No. 11, 2282-2283 (1955) Nov.

Chlorex (B, B-dichlorodiethyl ether) is used as an extraction solvent to separate lubricating stocks into paraffinic and naphthenic fractions. Chlorex is removed from the oils by distillation. Traces of hydrochloric acid are formed when Chlorex and oils are heated, thus creating a corrosive condition. Pilot plant was designed to study corrosion rates with various inhibitors (alcohols, organic phosphates, mercaptans and amines) and for use as a stripping still. Corrosion rates were determined from weight loss and exposure time of coupons inserted at appropriate locations in still. Table, diagram.—INCO. 11495

5.8.3, 5.8.4

Corrosion Investigations Related to Adsorption Studies. C. C. NATHAN. *Corrosion*, **12**, No. 4, 161t-168t (1956) April.

Investigations have been conducted on a variety of amines and organic acids, in attempts to correlate the structure of the molecules with their adsorption characteristics from benzene solutions at room temperature. Correlations were made also between molecular structure and the effectiveness of the film adsorbed on iron powder as an inhibitor to attack on the powder by aqueous acetic acid.

Adsorption and desorption data were quantitatively evaluated where possible. It was found that strongly adsorbed materials generally gave more protection to the coated powders than did weakly adsorbed, easily desorbed materials. Adsorption in a homologous series was found to increase, in general, as the solubility of the homolog decreased, in accordance with Traube's rule of adsorption. A secondary amine seems to be much less effective as an inhibitor than a primary amine having the same number of carbon atoms. Tertiary amines were adsorbed to a smaller degree than either primary or secondary amines.

Branching of the alkyl chain of aliphatic amines decreases the ease of adsorption from solution. Aromatic amines which contained more than one aryl group attached to the nitrogen were found to be adsorbed only weakly and to be poor corrosion inhibitors. The presence of multiple polar groups did not result in substantially greater adsorption as shown by adsorption isotherm data.

Correlations between inhibition by aromatic acids and adsorption from alcoholic solutions were poor. None of the adsorbed acids functioned as inhibitors. 11196

5.9 Surface Treatment

5.9.3

Effects of Polishing Media on the Corrosion Sensitivity of Metallic Surfaces. (In German.) R. WEINER AND G. KLEIN. *Metalloberfläche*, Sec. B, **9**, No. 9, 132B-134B (1955) September.

Authors have investigated the suspi-

is corrosion research one of your problems?

When you look into a corrosion problem do you ever want to know what has been published that might help you reach a solution?

Do you ever have questions about temperatures, velocities, pressures or other factors important in controlling corrosion?

Would it help you to know what has been tried already, successfully or not, to solve problems similar to the ones you face?

Did you ever spend hours or days searching through literature for information you remember seeing but can't remember where?

When you are asked about the suitability of a material for a certain job, can you learn quickly whether it ever has been used or not?

Almost every one working on corrosion control frequently faces these or similar problems. The convenient semi-automatic sorting of NACE punch cards makes these questions easy to answer. If you need answers to questions like these it will pay you to look into the punch card service.

NACE Punch Card Abstract Service

*Subscriptions Accepted on
Calendar Year Basis*

Some Back Issue Subscriptions Are Available

Write today for illustrated information on this valuable research tool to: A. B. Campbell, Executive Secretary, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

agents may
ly available
examined
ication indi-
the litera-
ned, when
11497

Corrosion
7. LAWSON,
1st Okla-
man, April
47, No. 11,

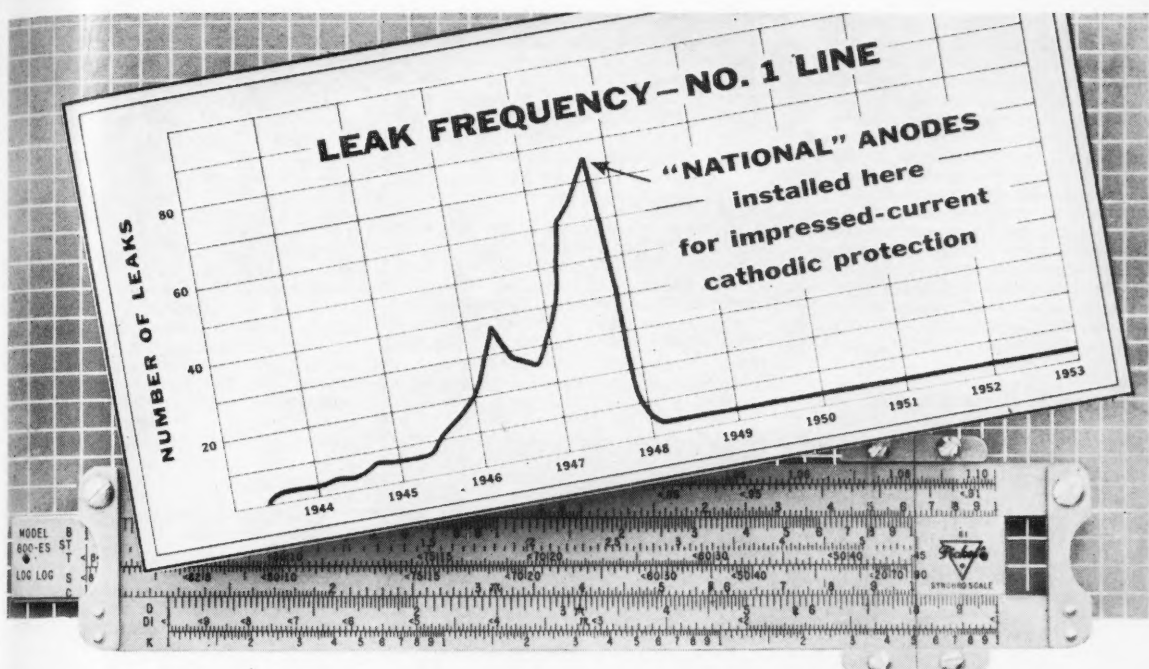
hyl ether)
nt to sepa-
rafinic and
is removed
Traces of
when Chlo-
creating a
it was de-
with vari-
phosphates,
or use as a
were deter-
posure time
te locations
11495

Related to
THAN, Cor-
1956) April.
ducted on a
c acids, in
ture of the
character-
room tem-
de also be-
the effec-
iron pow-
the powder

data were
possible. It
ed materi-
tion to the
y adsorbed,
orption in a
o increase,
the homo-
th Traube's
ary amine
e as an in-
having the
s. Tertiary
ller degree
ary amines.
of aliphatic
adsorption
ines which
group at-
ound to be
e poor cor-
of multiple
ubstantially
adsorption

on by aro-
m alcoholic
ie adsorbed
11196

ia on the
tallic Sur-
VER AND G.
B, 9, No. 9,
the suspi-



The chart tells the story...

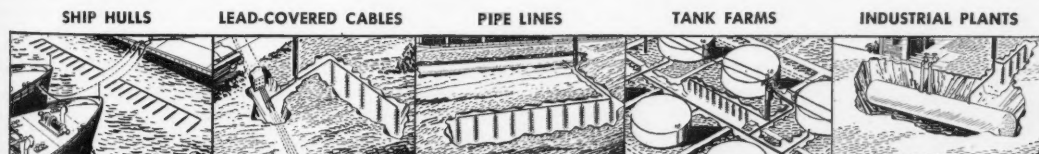
Underground or underwater, there's no need to suffer from corrosion headaches. This system tells you at a glance whether it's operative or not—and how effectively it's working. Impressed-current cathodic protection using "National" Graphite Anodes assures you low-cost dependable protection for your valuable investment.

Long life at low cost. Graphite's outstanding economy as a cathodic protection anode material has been proven by many years of service in soil and water environments. For example, a "National" standard 3" x 60" plain graphite anode, costing less than \$10, provides service life of over 100 ampere years when installed in soil in carbonaceous backfill. In salt water, the advantages of graphite are even more outstanding. A similar anode of NA graphite, costing less than \$12, has an estimated service life of approximately 500 ampere years at current densities as

high as 10 to 15 amperes per square foot!

Adaptable to your needs. "National" Anodes bring you graphite's advantages as a cathodic protection anode material in convenient, easy-to-use form. For burial in soil, standard cylindrical anodes are available in 3" x 60" and 4" x 80" sizes with either end cable connection or the Type QA connection, unsurpassed for strength, flexibility and dependability. Additional anode sizes are available for use in marine applications, including convenient plates for ship hull mounting. For distributed anode systems in soil or marine environments, "National" Anode Type QA assembled on cable is available from stock in 2" x 12", 2" x 20" and 3" x 30" sizes.

When you decide on the cathodic protection method for certainty, safety and economy, be sure to use "National" Anodes to get the best job done at the lowest overall cost. Write for catalog section S-6500.



Strike back at corrosion with **NATIONAL** Graphite Anodes



The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY • A Division of Union Carbide and Carbon Corporation, 30 East 42nd St., New York 17, N. Y.

Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco
IN CANADA: Union Carbide Canada Limited, Toronto

cion sometimes mooted. Aluminum, chromium-plate (over nickel on copper), copper, steel, brass, nickel-plate on copper, zinc, Zamak (zinc-aluminum-copper), all in sheet form, were polished with ferric oxide, chromic oxide, siliceous chalk, aluminum oxide and American tripoli powder, all made up into pastes with similar greases. The published specimens were exposed to various natural corrosive atmospheres: in some cases, there was some correlation between the abrasive used and corrosion. Polishing was carried out so that no perceptible residue of polishing paste remained, but no special action (boiling, degreasing, etc.) was taken to remove every trace.—BNF. 11043

5.9.3

Progress in Barrel Finishing. Part I. The Development and Technique of Barrel Finishing. C. J. A. KELLARD. *Electroplating*, 8, Nos. 3, 4, 95-96, 98; 149-152 (1955) March, April. (In Progress.)

Early developments and general principles of modern techniques; barrel finishing media and compounds; effects of operating variables (which differ for parts of different shapes). Bibliography of early British Patents 1879-1915.—BNF. 10938

5.9.3, 8.8.5

Abrasive Belt Grinding of Metals. H. N. DYER. Norton Company. *Ind. & Eng. Chem.*, 47, No. 12, 2500-2505 (1955) December.

Failure of coated abrasive grinding belt occurs either by fragmentation of abrasive grains or by attritious wear which dulls grain points. Rates of wear

depend on belt speed, work pressure, type of grinding fluid and the metal being ground. Tests on laboratory and commercial grinding equipment are reported. Metals tested included Types 303 and 304 and 1020 H.R. steel. Graphs show effects of cutting fluid and belt speed on centerless grinding.—INCO. 11476

5.9.4, 6.4.2, 3.8.4

Growth of Alumina Films on Single Crystals of Super-Purity Aluminium Alloys with 3% Magnesium. (In French.) J. HERENGUEL AND P. LELONG. "Rapports Presentes au Congres International de l'Aluminium, Paris, June, 1954," Vol. II, 1955, 63-66. Available from: R. Blanchard, 61 rue de la Tombe-Issaire, Paris.

Continuing the studies on the growth of anodic films the interference colors produced by white light on thin films are studied and rate of growth according to crystal orientation is confirmed; with same method the influence of current density on anisotropy of growth was investigated. Illustrations in color.—BNF. 11086

5.9.4, 6.3.6

Possible Applications and Technique of Anodic Brightening Process for Copper Alloys. (In German.) J. ELZE. *Metall*, 9, No. 21/22, 983-990 (1955) Nov.

Possible applications are brightening, smoothing, deburring removing corrosion products, etc. Experiments were carried out with a phosphoric bath (no details of composition) and good results are claimed with various brasses. Costs are calculated.—BNF. 11470

5.9.4, 1.6, 8.8.5

The Practice of Anodizing Aluminium.

(In German.) WALTHER W. HUBNER AND A. SCHILTKNECHT. Book, 1956, 408 pp. Aluminium-Verlag GmbH., Dusseldorf, Germany.

This handbook to the practical art of anodizing wastes no time on theory. Processes of chemical and electrolytic oxidation and brightening are covered (Secs. 1-3.4). As a logical sequence of these chapters a treatise on dyeing, sealing, after-treatment and printing is presented (Secs. 3.5-3.8). Recommendations concerning selection of material to be anodized (Sec. 4), and for layout and equipment of the shop (Sec. 5) are given. Methods of mechanical pretreatment (Sec. 6) and racking (Sec. 7) are described and, in a miscellaneous part, testing procedures (Sec. 8.1), standardization (Sec. 8.2), computations (Sec. 8.3) and maintenance (Sec. 8.4) are discussed. The concluding Section 9 embodies an extensive bibliography and an index.—ALL. 11343

5.9.4

A Critical Comparison of Aluminium Coating Methods. G. T. SINK. *Light Metal Age*, 13, No. 10/11, 21-23, 35 (1955) Oct.

Describes the seven treatment systems used at Douglas Torrance for applying protective coatings to aluminum airframe components. These are: chromate conversion treatments using Iridite No. 14 as applied to welded assemblies and to tubing and two forms of Alodine; chromic acid anodizing, sulfuric acid anodizing and Sanford Hard Coating. Tables compare advantages of the systems and give data on thickness, corrosion resistance to salt spray and abrasion resistance. Graph shows effect of various coatings on fatigue life of a 7075-T6 aluminum alloy.—INCO. 11068

6. MATERIALS OF CONSTRUCTION

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.14

Strengthening of the Oxide Film on Tin to Improve Corrosion Resistance. (In French.) S. C. BRITTON. *Metall. Corrosion-Industries*, 30, No. 355, 134-138 (1955) March.

Addition of alloy elements to the metal; chemical and electrochemical treatment of the surface; treatment of tin in a film-forming solution.—BTR. 10496

6.3.14, 3.8.2, 5.3.4

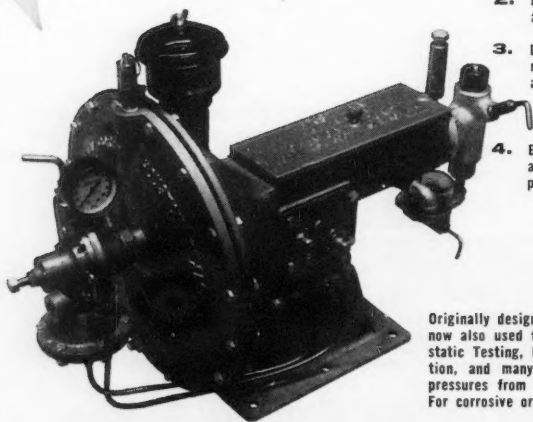
Electrochemical Behavior of Tin. Voltage-pH Equilibrium Diagrams of the Tin-Water System at 25°C. Corrosion of Tin. Electrolytic and Chemical Tinning. (In French.) E. DELTOMBE, N. DE ZOUBOV AND M. POURBAIX. Centre Belge d'Etude de la Corrosion, Rapport Technique, No. 25, 1955, 24 pp. Available from: Centre Belge d'Etude de la Corrosion (Cebelcor), 21 rue des Drapiers, Brussels, Belgium.

Discusses free enthalpies of standard formation at 25°C, equilibrium reactions and formulas, interpretation of diagram with respect to the stability of tin and its oxides, corrosion and tin plating. Tables, diagrams. 45 references.—BTR. 10746

6.3.14, 3.8.3, 5.9.4

The Anodic Behaviour of Tin in Sulphuric Acid. (In German.) W. MACHU, A. M. AZZAM AND G. M. HABASHI. *Metall.*

Texteam MSM 5001 diaphragm-operated chemical pump WITH 4 BUILT-IN FEATURES FOR ACCURACY, ECONOMY, EASE OF OPERATION



1. Simplicity of Design—makes repairs by non-technical personnel possible.
2. Ease of Operation—saves operators valuable time.
3. Dependable Accuracy—means more hours of operation without adjustment.
4. Economy in Both Initial Cost and Operation—means less cost per unit of work.

Originally designed for corrosion control work, now also used for Methanol Injection, Hydrostatic Testing, Blending, Evacuation, Dehydration, and many other kinds of work where pressures from 0 to 20,000 psi are required. For corrosive or non-corrosive chemicals.



TEXTEAM CORPORATION

DIVISION OF VAPOR HEATING CORP.
320 Hughes St., Houston, Texas

6723

TURNER AND
56, 408 pp.
Dusseldorf,

tical art of
on theory.
electrolytic
are covered
sequence of
yeing, seal-
ing is pre-
commenda-
material to
layout and
) are given.
retreatment
(7) are de-
aceous part,
standards
(Sec. 8.3)
e discussed.
mbodies an
an index.—
11343

Aluminum
INK. Light
21-23, 35

ment sys-
rrance for
to alumi-
These are:
ents using
welded as-
two forms
dizing, sul-
ford Hard
vantages of
a thickness,
spray and
shows effect
e life of a
CO. 11068

and

le Film on
Resistance.
N. Metaur.
55, 134-138
the metal;
reatment of
in a film—
10496

or of Tin
agrams of
C. Corro-
d Chemical
LTONBE, N.
entre Bege
port Tech-
lable from:
Corrosion
iers, Brus-

of standard
n reactions
of diagram
of tin and
in plating
ces.—BTR.
10746

Tin in Sul-
N. MACHU,
SHI. Metal-

oberfläche, Ser. A, 9, Nos. 4, 5, 58A-62A, 73A-75A (1955) April, May.

Like iron, nickel and thallium, tin shows two successive passivity phenomena on anodic treatment in sulfuric acid, one arising in the formation of Sn^{2+} ions, the other from simultaneous formation of Sn^{2+} and Sn^{4+} ions. Investigations (on purest analytical tin) of current density/time curves in sulfuric acid, valency of dissolved tin; potential of tin anodes. Resistance measurements on the surface film; polarization resistances at tin anodes.—BNF. 10541

6.3.14, 3.8.4

Oxidation and Recrystallization of Tin Under a Reduced Pressure. (In French.) JEAN-JACQUES TRILLAT. *Rev. met.*, 52, No. 5, 349-352 (1955) May.

Through the use of a furnace, at controlled temperature, it was possible to follow continuously the passage of tin from the crystalline state to the liquid state, then its progressive transformation into the oxides-stannous oxide and stannic oxide. Diagram, photographs. 7 references.—BTR. 10342

6.3.14, 5.3.2

Research on the Corrosion of Tin and on Its Protective Action on Iron. (In Italian). G. BIANCHI. *Metallurgia italiana*, 47, No. 5, 216-219 (1955) May.

Corrosion tests on tin and tin with steel in solutions of sulfuric, oxalic, tartaric, malic, citric and salicylic acid, with and without additions of chlorides and sulfates. Investigates tin-2% lead alloys. Graphs, photograph. 1 reference.—BTR. 10490

6.3.14, 3.2.2, 5.8.3, 4.4.9

The Corrosion of Tin in Solutions of Sodium Alkyl Sulphates. T. K. ROOS. *J. Applied Chem.*, 5, 10-18 (1955) January. Mechanism of pitting corrosion in solutions containing surface active agents. Graphs, micrographs. 22 references.—MR. 11490

6.3.14, 3.8.4, 4.7

Oxidation Rates of Molten Metals as Determined by a Recording Thermobalance. Part I. Tin. J. H. BILBREY, JR., D. A. WILSON AND M. J. SPENDLOVE. U. S. Bureau of Mines, Report of Investigations No. 5181, December, 1955, 24 pp.

Rates of oxidation of molten tin over temperature range 550 to 900°C, as determined by recording thermobalance, were found to vary widely for a given temperature. X-ray diffraction data indicated that probable cause of variations was the development of preferred orientations in crystals forming the oxide film. Photographs, diagrams, graphs, tables. 32 references.—BTR. 11321

6.3.15, 3.2.3

Electron Diffraction Study of Thin Layers of Titanium and Its Oxides. (In French.) PIERRE CONJEAUD. *J. recherches du centre national de la recherche scientifique*, No. 32, 273-290 (1955) Sept.

Examination of thin layers, obtained by vacuum condensation of the vapor of alkaline halide monocrystals, shows three types of structures. The formation of different oxides and their reciprocal orientation is investigated. Diagrams, graphs, table. 19 references.—BTR. 11292

6.3.15, 4.3.2

Rate of Dissolution of Titanium in Phosphoric Acid. (In French.) T. G. OWE BERG. *J. chim. phys.*, 52, No. 5, 363-366 (1955) May.

Rate of dissolution of titanium in 6N

to 28N phosphoric acid at 40, 50, and 60°C is proportional to normality. Graphs. 3 references.—BTR. 11288

6.3.17

Physical Metallurgy of Uranium. FRANK G. FOOTE. Symposium on Nuclear Metallurgy (Amer. Inst. Min. Met. Engrs.), 1955, 65-126.

Foote reviews the physical metallurgy of uranium metal and its alloys. The physical, thermal and crystallographic properties of uranium are tabulated. The following metallurgical aspects are discussed: 1) plastic deformation in α -uranium; 2) preferred orientation in α -uranium rod, sheet, strip, or powder compacts; 3) the effects of fabrication, impurities and degree of work-hardening on recrystallization and grain growth and the factors affecting grain-size

after recrystallization or transformation; 4) the growth of uranium single crystals; 5) the determination of thermal-expansion characteristics by X-ray or dilatometric methods; 6) the effects of thermal cycling on the dimensions and microstructures of uranium; 7) irradiation effects; 8) mechanical properties; 9) corrosion of uranium and uranium-rich alloys; 10) uranium alloys, including diagrams of the binary systems of uranium with aluminum, silicon, chromium, molybdenum, niobium, zirconium and titanium; and 11) transformation kinetics in uranium and uranium-chromium, uranium-molybdenum, uranium-niobium, uranium-zirconium and uranium-zirconium-niobium alloys. 18 references.—MA. 11393

6.3.17, 3.8.2

Electrochemical Behavior of Ura-

only vibra-pak anodes

offer all

11

SPECTROGRAPHICALLY ANALYZED
Assures highest degree of operating efficiency.

2

THIN SPIRAL CORE
Perfectly bonded — gives more useful current per anode.

3

UNIFORM BACKFILL
Exclusive VIBRA-PAK means longer anode life.

No matter what the installation — pipelines or well casing, marine or subsurface — VIBRA PAK is your best anode buy!

Standard Magnesium Corporation

P. O. BOX 1424C • TULSA, OKLAHOMA

nium, Equilibrium Diagrams of Tension-pH of the System $U-H_2O$ at 25°C. (In French.) E. DELTOMBE, N. DE ZOUBOV AND M. POURBAIX. *Cebelcor Rapport Technique* No. 31, February, 1956, 14 pp. Available from: Centre Belge d'Etude de la Corrosion, 21 Rue des Drapiers, Brussels, Belgium.

The following are included: Free enthalpies of the standard formation at 25°C, reactions and equilibrium formulae, equilibrium diagrams of tension-pH and interpretation. 11342

6.3.20, 3.2.3, 3.5.9

Scaling of Zirconium at Elevated Temperatures. Quarterly Status Report No. 10, September 2, 1955 to December 2, 1955. C. A. BARRETT, E. B. EVANS AND W. M. BALDWIN, JR. Case Inst. of Tech., Cleveland, U. S. Atomic Energy Comm., Pubn. No. 3120, December 8, 1955, 4 pp. —NSA. 11308

6.3.20, 3.5.9

Reaction Kinetics of Zirconium and Zircaloy-2 in Dry Air at Elevated Temperatures. L. F. KENDALL. Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-39190, Sept. 26, 1955, 25 pp.

Corrosion rates of sponge zirconium and Zircaloy-2 in dry air were measured at 500, 600 and 700°C. The reaction proceeds in two stages: initially the rate decreases with exposure time, approximating a cubic relationship; after sufficient exposure, the rate becomes a linear function of time. The rate constants calculated from the data and expressed by the Arrhenius equation are given. Ex-

trapolation of these data to lower temperatures indicates a service life of several years for these metals below 400°C.—NSA. 11433

6.3.20, 3.7.2, 1.6

Compositional Factors Affecting Corrosion Resistance of Zirconium in High-Temperature Water and Steam. WALTER K. BOYD, DANIEL J. MAYKUTH, ROBERT S. PEOPLES AND ROBERT I. JAFFEE. Battelle Memorial Institute. U. S. Atomic Energy Commission Pubn., BMI-1056, November 18, 1955, 94 pp.

An attempt was made to correlate the composition and structure of a number of sponge zirconium alloys with their corrosion resistance in hot water and steam. Increasing the carbon content of the sponge and crystal-bar melting stocks above their original value of 0.02 wt.% lowered corrosion resistance. Raising the nitrogen content at a given carbon content increased the rate of attack, but not over that normally associated with high nitrogen levels. Oxygen, in the range of 0.07 to 0.35 wt.% had no significant effect on the corrosion behavior of either sponge or crystal-bar zirconium. Small additions of nickel, iron, chromium and tin improved the corrosion resistance of the base materials, with iron and nickel being the most effective followed by chromium and tin. Additions of germanium, gold, iridium, palladium, platinum and ruthenium in the range of 0.25 to 4 or 8 wt.% resulted in no significant improvement in corrosion properties of zirconium. No correlation of corrosion resistance to structure could be made for the alloys containing oxygen, nitrogen and tin. The detrimental effect of carbon on the corrosion resistance of the sponge was correlated with the increased amount of the carbide phase. Optimum corrosion resistance in the nickel, iron and chromium alloys appears associated with the presence of critical amounts of the intermetallic compounds characteristic of these elements. (auth).—NSA. 11314

6.3.20, 3.8.4, 3.5.9

An Investigation of Scaling of Zirconium at Elevated Temperatures. Quarterly Status Report No. 9 (for) June 2, 1955, to September 2, 1955. H. M. GREEN, H. E. TUCHSCHMID AND W. M. BALDWIN, JR. Case Inst. of Technology. U. S. Atomic Energy Comm. Pubn., AECU-3075, Sept. 6, 1955, 9 pp.

To obtain a better understanding of the mechanism involved in the scaling behavior of zirconium, kinetic studies were made of the weight pickup in air after pretreating by exposure to oxygen or nitrogen and exposure to air, oxygen or nitrogen and removal of the resulting surface compounds. The results of these experiments are discussed. (auth). —NSA. 11482

6.3.21, 1.4

Thorium: A Bibliography of Published Literature. W. D. PRATER, E. F. JOY AND E. G. ESTERBROOK, compilers; ROBERT E. ALLEN, editor. Mound Lab., Miamisburg, Ohio and Technical Information Service, AEC. U. S. Atomic Energy Commission Pubn., TID-3044 (Suppl. 1), June, 1955, 299 pp.

This supplement to TID-3044 contains annotated references to published literature which appeared in Chemical Abstracts from 1906 to 1952. Author and subject indexes are included. (auth). —NSA. 11492

6.3.21, 3.8.2

Equilibrium Potential/pH Diagram for the System Manganese-Water at 25°C. A. M. MOUSSARD, J. BRENET, F. JOLAS, M. POURBAIX AND J. VAN MUYLDER. *Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics* (Poitiers, 1954), 1955, 190-197.

Calculations are made of the equilibria between manganese, manganous oxide, manganese dioxide, manganic oxide, Mn_2O_3 , manganous hydroxide, water, and the aqueous ions, H^+ , Mn^{2+} , Mn^{3+} , MnO_2H^+ , MnO_4^- and MnO_4^{2-} at 25°C and are represented in a diagram of electrode potential versus pH; for manganese dioxide, the free energy of pyrolysis has been used, but it appears that other allotropic forms can exist; of the two forms of manganic oxide, only the more stable one can be obtained electrolytically; no account has been taken of the possible solid solution of oxide. Conclusions are drawn about the electrochemical properties of manganese and of its oxides and aqueous solutions. The diagram indicates that the best yield and purity in the electrolytic production of manganese should be at cathodic pH slightly less than the pH of saturation of manganous hydroxide, which for M-Mn, is 7.4; this is in agreement with practice. The behavior of manganous oxide in Leclanche cells is discussed. 18 references.—MA. 11439

6.3.21, 4.6.5

Corrosion of Thorium and Thorium Binary Alloys in Distilled Water at 100 and 200°C. W. E. BERRY, H. A. PRAY AND R. S. PEOPLES. Battelle Memorial Institute. U. S. Atomic Energy Commission Pubn., BMI-951, Sept. 29, 1954 (Declassified Sept. 30, 1955), 18 pp.

The corrosion behavior of thorium and several of its alloys in distilled water was studied. Unalloyed thorium was found to possess excellent corrosion resistance in boiling distilled water. Thorium alloyed with zirconium was equally resistant; however, additions of aluminum, chromium, lead, molybdenum, nickel, niobium, silicon, titanium or vanadium either lowered or completely destroyed its corrosion resistance. Neither unalloyed thorium nor any of the above alloys were resistant to water at 200°C. Alloys containing titanium or zirconium exhibited less attack than unalloyed thorium and their corrosion resistance increased as alloy content increased. Raising the test temperature from 100 to 200°C increased corrosion rates as much as 1000-fold. (auth). —NSA. 11289

6.4 Non-Ferrous Metals and Alloys—Light

6.4.1, 6.3.15

How Corrosion Studies Have Influenced Light Metal Usage. F. W. FINK. *Metal Finishing J.*, 1, No. 7, 324-325, 332 (1955) July; *Battelle Technical Review*, 4, No. 2, 15-18 (1955) Feb.

By carefully selecting their uses and making them corrosion resistant for specific applications, magnesium, aluminum and titanium can be made more useful to many industries. Alloy of magnesium with 11 percent lithium has excellent corrosion resistance and less than usual sensitivity to impurities. Thin sheets of aluminum alloys are best protected by cladding with pure aluminum. Iron or copper traces in water

ACIDS • CAUSTICS • MOISTURE

BETTER PROTECTION FROM CORROSION CAUSED BY

KERPON

PROTECTIVE COATINGS

Formulated of the sensationally successful EPOXY RESINS

PROVEN SUPERIOR performance in actual use under most extreme corrosion conditions—as container and pipe linings—as product and equipment finishes.

PROVEN SUPERIOR in resistance to practically all natural and chemical corroding elements including many acids.

PROVEN SUPERIOR in flexibility, color and gloss retention, long life and positive adhesion to most metals including iron and steel.

PROVEN SUPERIOR in reducing costly deterioration, replacement, maintenance and customer complaints.

For a faster, low cost solution to YOUR corrosion problems write —

KERR CHEMICALS, INC.
BOX 443-C PARK RIDGE, ILLINOIS

• INTERIOR OR EXTERIOR •

Diagram for
er at 25C.
F. JOLAS, M.
Proc. 6th
electrochem.
s (Poitiers).

e equilibria
ous oxide,
nic oxide,
de, water,
Mn²⁺, Mn³⁺,
at 25C
am of elec-
or manga-
y of pyro-
appears that
ist; of the
e, only the
ained elec-
been taken
of oxide.
he electro-
anese and
ations. The
best yield
production
thodic pH
saturation
which for
ment with
manganous
discussed. 18
11439

Thorium
ater at 100
PRAY AND
d Institute.
sion Publ.,
sified Sept.

thorium
stilled wa-
ames tho-
excellent
g distilled
zirconium
ver, addi-
um, lead,
t, silicon,
owered or
rosion re-
rium nor
resistant
containing
d less at-
and their
as alloy
test tem-
eased cor-
d. (auth).
11289

and

ve Influe-
W. FINK.
4-325, 332
Review,

uses and
stant for
n, alumi-
ade more
y of mag-
a has ex-
and less
mpurities.
are best
re alumi-
in water



At a huge new sports stadium in Minnesota...

"SCOTCHRAP" rolls on easy ... even in zero weather!

"Scotchrap" conforms smoothly, handles easily at high or low temperature — and the pressure-sensitive adhesive sticks tight, too — even at 0°-10°F!

Johnson, Drake & Piper, Inc., General Contractors on the new Metropolitan Sports Stadium near Minneapolis, Minnesota, prefer "Scotchrap" Brand Pipe Insulation for these reasons — and many more. You see, there's no danger when applying "Scotchrap". No special equipment

is needed. Just roll it on, and corrosion is sealed out.

"Scotchrap" is a tough vinyl plastic tape that resists abrasion above or below ground, resists galvanic and electrolytic action, resists damage from oil, water, acids, alkalis, weathering and sunlight. *Make sure you get the tape with the green adhesive.*

Sold by the square in 1", 2", 4", 6" and 8" widths — 100-foot rolls. Order a supply today!

REG. U.S. PAT. OFF.

SCOTCHRAP Pipe Insulation BRAND

The term "SCOTCHRAP" is a registered trademark of Minnesota Mining and Manufacturing Company, St. Paul 6, Minn. Export Sales Office: 99 Park Ave., New York 16, N.Y. In Canada: P.O. Box 757, London, Ontario.



promote corrosion of aluminum piping; sodium chromate added to slightly buffered water prevents attack. Titanium is one of the most corrosion resistant materials available with no equal to resist action of sea water. However, titanium is subject to stress corrosion.—INCO. 10872

6.4.2

On Comparison Test Between 3S and Modified 3S. HIDEHISA OSAWA, YUZO NAKAMURA AND MOTOI NISHISAKA. *Light Metals* (Japan), No. 15, 26-30 (1955) May.

Comparison tests were made between 3S and modified 3S. Aluminum-manganese-magnesium (manganese 0.7, 1.0%; magnesium 0.25, 0.5%) alloy sheet rolled from non-preheated slab had superior corrosion resistance to sodium hydroxide solution. Its orange peel phenomenon seemed to be the same as in preheated 3S sheet but its workability and corrosion resistance to hydrochloric acid solution decreased slightly.—ALL. 10595

6.4.2

The So-Called Well-Water Blackening of Aluminum and Its Prevention. (In German.) D. ALTENPOHL. *Metalloberfläche*, Ser. A, 9, No. 8, 118-121 (1955) August.

Effect of hard tap and well water on pure aluminum and aluminum alloys; chemical preventive measures; methods of testing an aluminum surface for its susceptibility to blackening; protective effect of a bohmite film. Micrographs, photographs, table. 4 references.—BTR. 10472

6.4.2

100 Years of Aluminum as an Engineering Material. *Engrs' Digest*, 16, No. 5, 217-257 (1955) May.

A series of papers on history and present status of development, production, fabrication and applications of aluminum and its alloys. Papers include: The History and Development of Aluminum and Its Alloys, A. von Zeerleder (pp. 217-220); British Standards for Aluminum, E. Elliott (pp. 221-226); The Welding of Aluminum and Its Alloys, J. F. Lancaster (pp. 227-232) Joining Aluminum by Soft Soldering, H. C. Watkins (pp. 233-236); The Metallurgical Control of High-Quality Aluminum Forgings, T. E. Murch (pp. 238, 243); Die-Casting in Aluminum, F. G. Woolard (pp. 239-243); Finishes for Aluminum, A. W. Brace (pp. 244-247, 252); Aluminum-Alloy Bearings, E. A. G. Liddiard (pp. 248-252); The Liability to Fatigue Failure of Aluminum-Alloy Structures, T. Haas (pp. 253-257).—BNF. 10519

6.4.2

Investigation of Structures of Continuously Cast Bars of Pure Aluminum (99.5%) and Raffinal. (In German.) D. ALTENPOHL. *Z. Metallkunde*, 46, No. 8, 535-544 (1955) August.

Investigates the occurrence of micro- and macro-segregation in continuously cast bars of 99.5 percent aluminum and Raffinal (99.99 percent aluminum); impurities occurring at the grain boundaries were investigated with the hot stage microscope, the grain boundary material melting at 630-650°C, due to enrichment (up to 10-fold compared to an average analysis) by impurities. The macroscopic segregations can produce porosity after recrystallization annealing of sheet, a local deterioration of corrosion resistance and can influence working properties.—BNF. 10689

6.4.2

Aluminum Alloys. H. W. FRITTS AND R. L. HORST, JR. *Ind. and Eng. Chem.*, 47, No. 9, 1946-1952 (1955) September.

Following an introductory part dealing with recent research concerning mechanical properties and corrosion resistance of aluminum alloys a general survey of the field of their applications is given. The material presented includes outdoor applications, i.e., structural uses and roofings, heat exchangers, general process applications in the chemical industry and special uses in various branches of the chemical and related industries.—ALL. 10821

6.4.2, 1.6

Aluminum Handbook. (In German.) JOHANNES REIPRICH AND WILHELM V. ZWEHL, editors. Book, 11th Edition, 1955, 965 pp. Aluminum-Verlag GmbH, 26/29 Jagerhofstrasse, Dusseldorf 22a, Germany.

A thorough exposition of aluminum from the technical and industrial point of view. The 400 references and 170 tables cover the data on aluminum, with information taken from sources all over the world. The editors have canvassed 20 periodicals for additional data.

For the worker in aluminum proficient in German or who has translating services at his command this should be a useful and often referred to book. 10628

6.4.2, 1.7.1

The Corrosion of Aluminum and Its Alloys. C. GROOT AND R. M. PEEKEMA. Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-36692, May, 1955, 36 pp.

Flow Cup Laboratory was established to screen aluminum alloys for corrosion in pile water as measured by weight loss, solution potentials, and galvanic currents. Photographs, tables, graph, 4 references.—BTR. 10768

6.4.2, 2.3.2

Simple Spot Tests for Aluminum Contaminants. H. S. HILBORN AND R. C. PUGH. *Nucleonics*, 13, No. 10, 46-47 (1955) October.

Electrographic sampling and colorimetric spot tests to detect and identify impurities in aluminum, susceptible to cause corrosion of reactor components, are listed and the procedures are described.—ALL. 10818

6.4.2, 2.3.6

Tunnel Etching of Aluminum. F. J. BURGER, V. F. G. TULL AND P. H. HARRIS. *Bull. Inst. Metals* (England), 3, Part 1, 6 (1955) September.

Letter to the editor. By the use of suitable electrolytic etching technique, aluminum foils of 99.8 percent purity were etched so that the form of attack was restricted very largely to tunneling. The method used was to make the foil the anode in a bath consisting of 0.01N HCl + 12.3 g./l. NaCl, maintained at a temperature of 90°C with an aluminum cathode and a current density of 0.03 amp./sq. cm., the current being supplied from a battery. The etch structure produced was examined in the electron microscope by means of the oxide-replica technique, the replica being stripped in a mercuric chloride solution. Two stereoscopic electron micrographs views are illustrated. The tunnel structure appears to be related to three

mutually perpendicular directions but a complete explanation of the form of attack has not yet been established.—ALL. 10731

6.4.2, 3.2.2

Influence of Specimen Area on the Pitting Probability of Aluminum. P. M. AZIZ AND HUGH P. GODARD. *J. Electrochem. Soc.*, 102, No. 10, 577-579 (1955) Oct.

The pitting probability of 2S aluminum was determined in Kingston tap water as a function of area, for areas ranging in size from 0.06 sq. cm. to 243 sq. cm. The pitting probability was found to vary uniformly with area, from 0.001 to 1 as the area increased from 0.06 sq. cm. to 60 sq. cm.; extrapolation indicated that the pitting probability becomes zero at an exposed area of about 0.055 sq. cm. This work supports the contention that pitting sites in aluminum are not specific macrodefects in the metal surface, but rather arise in a random fashion through the interaction of myriads of anodic and cathodic elements on the metal surface.—ALL. 10685

6.4.2, 3.5.8, 3.7.3

Some Microscopical Observations on the Effect of Fatigue and Corrosion Fatigue Stresses on DTD 683. C. A. STUBBINGTON AND P. J. E. FORSYTH. Royal Aircraft Establishment, Tech. Note No. MET. 211 (U. S. NACA, Rept. No. N38244), February, 1955, 8 pp.

DTD 683 alloy (aluminum-copper-magnesium-zinc) shows transcrystalline failure and slip band exudation when subjected to cyclic stress except under conditions of corrosion fatigue when some intercrystalline cracking was observed. Investigation showed that corrosion is an operative factor in service fatigue failures and that atmospheric moisture is an effective corrosive agent for the alloy. Tendency to produce intercrystalline corrosion fatigue failure is greatest in certain conditions of heat treatment. Suggestions are made for modification of existing heat treatments to improve corrosion fatigue properties. Photomicrographs.—INCO. 10365

6.4.2, 3.5.8, 3.7.4

Study of Effects of Microstructure and Anisotropy on Fatigue of 24S-T4 Aluminum Alloy. H. A. LIPSITT, G. E. DIETER, G. T. HORNE AND R. F. MEHL. National Advisory Committee for Aeronautics, Technical Note No. 3380, March, 1955, 42 pp.

Results of investigation of statistics on effects of variation in microstructure (extruded and extruded plus recrystallized) on fatigue properties of 24S-T4 aluminum alloy notched specimens tested in both the longitudinal and transverse directions. Anisotropy is found in fatigue strength only for material in extruded condition. Correlation tests with unnotched extruded longitudinal specimens showed that there is more scatter in unnotched than notched specimens; within range of stresses investigated, fatigue-strength reduction factor K_f increases with increasing stress. Tables, graphs, photomicrographs.—INCO. 10857

6.4.2, 3.5.9

Influence of Heating on the Mechanical Properties and Corrosion Resistance of P-AG5 Alloy. (In Italian.) D. GUALANDI AND G. LUFT. *Alluminio*, 24, No. 3, 229-240 (1955) May.

Investigations were conducted on the

variations occurring in the mechanical and corrosive properties of wrought aluminum-magnesium alloys, not perfectly stabilized, when subjecting them to temperatures higher than room temperature and keeping them there for a prolonged time. The specimens tested consisted of sections of aluminum plates reduced by rolling to 1-1.4 mm thickness, work hardened and some of them annealed. The material used contained 4.5-3.6% magnesium, $\leq 0.4\%$ iron, $\leq 0.3\%$ silicon, 0.1-0.4% manganese and $\leq 0.05\%$ copper, as alloying elements. Variations of the mechanical characteristics observed at 80 and 150°C are tabulated. It is demonstrated that elongation has a tendency to increase while hardness, braking stress and elastic limit tend to decrease as a result of heat applied. At these stages metallographic observations show a rapid precipitation of the β phase (Mg_2Al_3) at the grain boundaries. Results of stress-corrosion tests, carried out in 3 percent salt solution activated with 1 percent hydrochloric acid, are reported and the apparatus used described. The effects of annealing on stress corrosion are investigated and it is demonstrated that liability to failure becomes actual after 240 hours at 80°C temperature and after four hours at 150°C; by controlled annealing and very slow cooling such behavior may be improved. Comparative figures of a gas-volumetric analysis and of the findings concerning the stress-corrosion tests are given.—ALL. 10588

6.4.2, 3.7.2

On the Age Hardenable and Corrosion-Resistant Aluminum-Magnesium-Silicon Ternary Alloys. Part II. MASAO KATO, YOSHIKATA SASAKI AND OSAMU ISHIKAWA. *Light Metals* (Japan), No. 14, 32-46 (1955) March.

As part of a systematic investigation of alloys hardened by magnesium silicide precipitation and having good corrosion-resistant properties, the combined effects of 0.1-1.0% iron, 0.0-0.4% copper, 0.3-0.7% manganese and 0.25% chromium have been assessed in three kinds of base alloys: A (1.1% magnesium, 0.65% silicon, balance aluminum), B (0.75% magnesium, 1.3% silicon, balance aluminum) and C (1.3% magnesium, 1.3% silicon, balance aluminum), which were considered typical of the aluminum-magnesium-silicon ternary system. All alloy specimens were hot and cold rolled to sheet 1 mm thick; and prepared in the following heat treatment states, by respective treatment: O (450°C for 2 hr.), T4 (520°C for 2 hr., water quenched and room-temperature aged for 10 days) and T6 (520°C for 2 hr., water quenched and tempered at 175°C for 10 hr.). Corrosion tests were carried out for one and three month periods in a solution of 5.85% sodium chloride and 0.3% hydrogen peroxide. The effects of the three added elements were as follows: copper increases the strength of the alloy, while it has detrimental effects on corrosion resistance. Fe is detrimental to mechanical properties and corrosion resistance.—ALL. 10415

6.4.2

Super-Purity Aluminum and Its Alloys and Discussion. F. A. CHAMPION AND E. E. SPILLETT. *Sheet Metal Inds.*, 345, No. 33, 25-38 (1956) January.

The refining process for super-purity aluminum is briefly stated. Its properties include: excellent corrosion resistance,

relative softness with high ductility, easy workability and low rate work hardening, high thermal and electrical conductivity, excellent anodizing properties and high reflectivity. Typical values of some of its properties are compared with those of lower purity aluminum. Super-purity aluminum can be readily formed by the operations of pressing, spinning, etc. Corrosion resistance is directly related to the overall purity of the aluminum. Characteristics of anodized finishes on super-purity aluminum are discussed. Advantages of cladding high copper alloys with super purity aluminum are considered. 11301

6.4.2

The Properties of Hiduminium 100 (SAP) in Sheet Form. W. M. DOYLE. Paper before Sheet & Strip Metal Users' Tech. Assoc., Spec. Conf. on Modern Materials, London, October 10-11, 1955. *Sheet Metal Inds.*, 32, No. 344, 889-898; disc., 902-906, 922 (1955) Dec.

Discussion of properties of sintered aluminum powder products (SAP), marketed in Britain as Hiduminium 100, begins with manufacture of powder, compacting and sintering, the effect of oxide content and manufacture of sheet and covers tensile properties at room and elevated temperatures, creep strength, fatigue endurance, corrosion resistance, bend properties, formability and joining. Remarkable properties of Hiduminium 100 are due to oxide films formed around particles during production of powder. Hiduminium 100 recovers its full original room-temperature mechanical properties after soaking for long periods at high temperatures. Material has excellent resistance to intercrystalline and stress corrosion. By application of Dy-

zacking technique, it is possible to deep draw and form contours in sheet not amenable to usual forming methods. Physical constants are given. Tables, graphs.—INCO. 11463

6.4.2

Influence of Purity on the Corrosion of Super-Purity Aluminum. (In French.) F. MONTARIOL. Rapports Presentes au Congres International de l'Aluminium, Paris, June, 1954, Vol. II, 1955, 23-26. Available from: R. Blanchard, 61 Rue de la Tombe-Issoire, Paris.

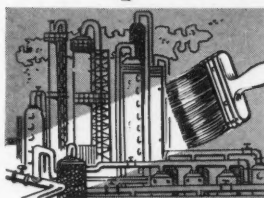
Super-purity aluminum (99.99 and 99.998 percent) shows marked preferential boundary attack in 15 percent hydrochloric acid anodic corrosion tests; as purity increases speed of attack decreases; results of tests with zone-melted aluminum (purity > 99.998 percent), heat treated then cooled slowly or quenched.—BNF. 11090

6.4.2

Aluminium-Copper-Cadmium Alloys. E. A. G. LIDDIARD AND H. K. HARDY. *Metal Treatment and Drop Forging*, 23, No. 125, 67-71 (1956) February.

The aluminum-copper-cadmium series of alloys has properties which compare favorably with those of the Duralumin type alloys and show certain advantages, particularly in their fabricating properties. Small quantities of cadmium, indium or tin added to aluminum-copper alloys produce accelerated artificial ageing and higher maximum properties. The ageing process in ternary aluminum-copper-cadmium alloys is currently under investigation. Electron microscopic examination suggests that θ was nucleated preferentially to give very much

2 NEW PAINTS for problem surfaces

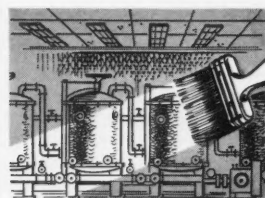


to galvanize
by brush or spray:

ZINC SHIELD*

- 95% pure zinc coating
- paints safely over irremovable rust
- no special surface preparation
- renews worn galvanized metal

*Zinc-rich coatings were
featured in the August 9 issue
of THE IRON AGE



for maximum protection
against chemicals, moisture:

Rubber-Coat

LIQUID NEOPRENE

- maximum resistance to acids, caustics, solvents, chemicals
- withstands abrasion, chipping, cutting
- dries in minutes — requires no undercoat
- wide temperature range — lows to 180° or over

Full information by return mail. Write:



THE WILBUR & WILLIAMS CO.

Boston (Brighton) 35, Mass.

finer particles than occurred in the binary aluminum-copper alloys. The solid solubility of cadmium in aluminum increases markedly with temperature, being negligibly small at temperatures below about 200°C and rising to about 0.4 percent at 649°C. At 530°C the solubility is 0.1-0.2 percent. Corrosion resistance is similar to copper-containing alloys so that some protection is necessary when exposed to corrosive atmospheres.—ALL. 11345

6.4.2

Service Failures of Aluminum Die-Casting Dies. G. A. ROBERTS AND A. H. GROBE. *Metal Progress*, 69, No. 2, 58-61 (1956) Feb.

The three most common types of failure of aluminum die-casting dies: heat

checking, pitting and impingement soldering are discussed. Heat checking and one kind of pitting are attributed to the combined effects of stress and oxidation. A second type of pitting is said to be the result of breaking of the semi-protective oxide film and subsequent reoxidation. Impingement soldering is actually a mechanical entrapment of aluminum in surface flaws. To avoid these failures recommendations are given concerning proper heat treatment and manufacturing procedure of the dies.—ALL. 11349

6.4.2, 1.6, 8.3.5

Aluminium with Food and Chemicals. Brochure, November, 1955, 89 pp. Northern Aluminium Co., Bush House, Aldwych, London, W.C. 2.

Mechanical properties of cast and

wrought aluminum alloys and corrosive effect of different foodstuffs. Effect of various substances (about 500 listed alphabetically) on aluminum and aluminum alloys, distinguishing between uniform, pitting, galvanic, crevice and intercrystalline corrosion. Effect of chemical or electrochemical oxidation, cladding, lacquering, painting, cathodic protection and inhibitors.—BNF. 11422

6.4.2, 2.3.4, 3.5.11, 4.4.3

Corrosion Testing of Aluminum. Part I. High Velocity Test Method in Aqueous Solutions. SUMNER B. TWISS AND JACK D. GUTTENPLAN. *Corrosion*, 12, No. 6, 265t-270t (1956) June.

A technique of corrosion testing, involving spinning of aluminum disks in aqueous solutions at high velocities, was used to investigate the effect of various natural waters and antifreezes on aluminum corrosion. Type of aluminum used was No. 100 aluminum brazing sheet, having zinc-aluminum cladding on one side and silicon-aluminum cladding on the other. It was established that an increase in velocity of movement up to a maximum peripheral velocity of 4700 feet per minute (12,000 rpm) is accompanied by a systematic increase in corrosion rate reaching very high values in some waters. Type of corrosion occurring at higher velocities is similar to that occurring at low velocities and in service. Aqueous solutions particularly corrosive were those combining high chloride ion concentration and high alkalinity (as OH^- or CO_3^{2-} ion), such as Royal Oak, Michigan, tap water. High alkalinity (up to pH 11) appears to cause severe attack of aluminum even in absence of chloride ion.

In permanent antifreeze solutions, Royal Oak tap water—ethylene glycol (1:1), an increase in velocity appeared to reduce an induction period that occurs before rapid corrosive attack sets in. In Royal Oak tap water-isopropyl alcohol solutions, velocity had no effect, corrosion remaining low at all velocities for the 200 hour test. Ethylene glycol appeared to accelerate corrosion and alcohols to reduce corrosion in all waters tested. 11415

6.4.2, 3.2.2

Tunnel Etching of Aluminium: Letter to the Editor. C. EDELEANU. *Bull. Inst. Metals* (England), 3, Pt. 4, 33 (1955) December.

In a study of the pitting mechanism of aluminum in chloride solutions carried out by the author, he came to the conclusion that the anodic reaction was an autocatalytic process at low rates of attack. Thus at any given applied current the attack area should become restricted to a small proportion of the surface and lead to pitting. If the applied current is constant the attacked area should also remain constant. The high rate of attack once established by the autocatalytic process should be most easily maintained at those places from which diffusion is most difficult, so that in a pit crack or in this case tunnel, the most likely place of attack is at the tip. The walls should remain unattacked.—ALL. 11467

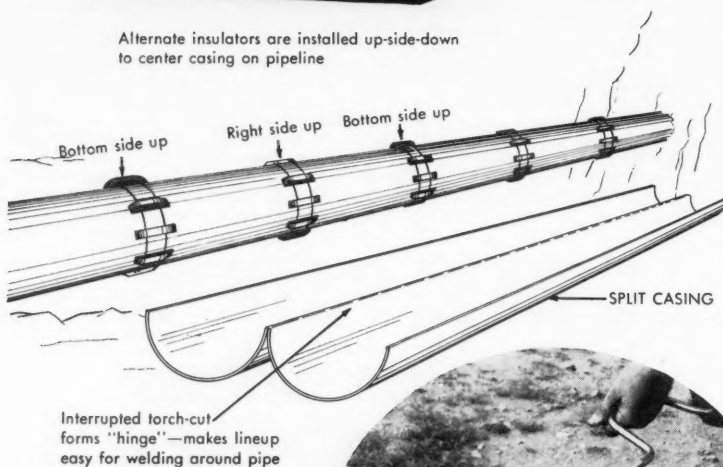
6.4.2, 3.2.2, 3.7.4

The Interpretation of Etch Patterns on Aluminium. A. J. FORTY AND F. C. FRANK. *J. Phys. Soc. (Japan)*, 10, No. 8, 656-663 (1955) August.

Examination of etch patterns produced

**Here's an easy way
TO INSTALL CASINGS ON
EXISTING PIPELINES**

Alternate insulators are installed up-side-down to center casing on pipeline



**WMSON
CONCENTRIC
SUPPORT
INSULATORS**

"STANDARD OF THE INDUSTRY"

WMSON THINsulators are used when clearance between pipe & casing is at a minimum



Write for literature

T.D. Williamson, Inc.

P. O. BOX 4038 TULSA 9, OKLAHOMA
REPRESENTATIVES: HOUSTON • PITTSBURGH • PLAINFIELD, N.J. • AMARILLO •
JOLIET, ILLINOIS • LOS ANGELES • SAN FRANCISCO • BARTLESVILLE, OKLA. •
SEATTLE • EDMONTON, LONDON, ONT. • CALGARY • VANCOUVER, B.C. •
BUENOS AIRES • CABIMAS, ZULIA, VENEZUELA • DURBAN, NATAL,
SOUTH AFRICA • PARIS, FRANCE

corrosive
Effect of
listed al-
d alumi-
green uni-
nd inter-
chemical
cladding,
protection
11422

um. Part
in Aque-
VISS AND
12, No.

isting, in-
disks in
ties, was
f various
on alu-
luminum
brazing
cladding
um clad-
established
movement
elocity of
(n) is ac-
crease in
h values
sion oc-
similar to
s and in
rticularly
ng high
nd high
such as
er. High
pears to
um even

ns, Royal
ol (1:1),
ed to re-
t occurs
ets in. In
l alcohol
ct, corro-
cities for
lycol ap-
and alco-
l waters
11415

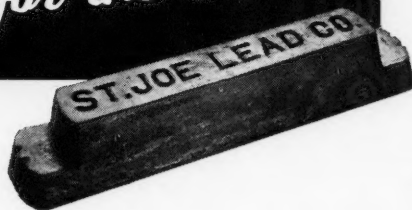
n: Letter
Bull. Inst.
3 (1955)

mechanism
ions car-
ne to the
tion was
rates of
died cur-
come re-
of the
the ap-
attacked
ant. The
ished by
be most
ces from
y, so that
nnel, the
t the tip.
tacked.—
11467

Patterns
ND F. C.
0, No. 8,
produced

A Job for Chemical Lead

and the Chemical Lead for the Job!



A method of protecting lead-lined vessels under high temperature conditions is to cover the metal with an inner lining of special acid-resistant brick. The installation shown above is a sulfuric acid concentrator, 16 ft. in diameter and 24 ft. high. Some 19 tons of chemical lead were used in lining the vessel. This type of construction is used commonly in the 450°F range and has been used at higher temperatures. The brick lining provides a temperature gradient to insulate the lead. Since no aggregate material can be entirely impervious to seepage, the corrosives leaking through are stopped by the lead lining and thus prevented from destroying the steel supporting structure. Photo courtesy Chemsteel Construction Co., Inc.

TYPICAL ANALYSIS OF ST. JOE CHEMICAL LEAD

Silver . . . . .	.0100%	Arsenic-Antimony-Tin	
Copper . . . . .	.06	Combined . . . . .	.0002%
Bismuth	Nil	Cadmium . . . . .	.0002
Zinc . . . . .	.0001	Cobalt & Nickel . . . . .	.0046
Iron . . . . .	.0001	Lead by difference	99.92+

Among the common metals, lead has no equal in its value to the chemical industry as a construction material for handling and controlling corrosives. The metal's utility in this field is well documented by a wealth of available performance records. The protection afforded by lead is the end-result of an inherent chemical property which is unique with the metal. Exposed to most corrosives, lead automatically forms upon its surface an insoluble, tightly adherent film of salts which henceforth acts as an effective barrier against further corrosion. The uncommon property of the common metal lead to forge its own protective armor is the reason why more than one-third of all the lead consumed annually in this country is used primarily for its resistance to corrosion.

St. Joe Chemical Lead is the most extensively used brand of lead in the chemical industries. Hundreds of thousands of tons are now in use—especially where operating conditions are severe. The metal is an exclusive product derived from the huge ore bodies of southeast Missouri which have been owned and operated by this Company since 1865. Owing to the unusual nature of these ores, there is present in the lead smelted from them a combination of copper and small amounts of other elements which produces a grade of lead particularly immune to the attack of most corrosives. At the same time, this natural chemical lead has a lower creep rate and a higher resistance to fatigue failure than lead produced from any other ores.

ST. JOSEPH LEAD COMPANY

250 PARK AVENUE, NEW YORK 17, NEW YORK

THE LARGEST PRODUCER OF LEAD
IN THE UNITED STATES

on aluminum polycrystals by etching with Lacombe's etchant (a concentrate mixture of nitric acid, hydrochloric acid and hydrofluoric acid) suggests that etch pits are produced only where there is a precipitate of impurity present in the surface and that these are located on dislocations which therefore can be regarded as an indirect cause of etching. It is tentatively estimated that, at best, only 60 or 70 percent of dislocations in super-purity (99.999 percent) aluminum produce etch pits. A discontinuous precipitate is necessary to explain why etch patterns cannot be reproduced pit-for-pit after intermediate polishing.—MA. 11413

6.4.2, 3.7.2

Study of the Effects of Magnesium, Silicon and Manganese on the Properties of JIS H5201 FAIACI. MOSAO KATO AND YASUJI NAKAMURA. *Light Metals* (Japan), No. 17, 71-74 (1955) Nov. 10.

The effect of content variations of magnesium, silicon and manganese in the specified range of JIS H5201 FAIACI (approximately corresponding to Alcoa 214) were investigated with respect to mechanical properties, casting behavior and corrosion resistance. The results obtained are as follows: 1) Silicon has a remarkable effect on tensile properties especially reducing its ductility but has little influence on its corrosion resistant properties. 2) Magnesium increases the tensile strength and 0.2 percent proof strength proportionally with its content but decreases elongation. Alloys with higher magnesium content are more difficult to melt and cast. 3) Manganese has little effect on mechanical properties but improves the sensitiveness to over-heating and deterioration of corrosion resistance by iron content.—ALL. 11451

6.4.2, 3.7.2

A Study of the Light Casting Alloy A-Z5G; Effect of Chromium and Copper Additions on the Mechanical Properties and Corrosion Resistance. (In French.) L. GRAND, A. GUILHAUDIS AND A. SAULNIER. *Rev. Met.*, 52, No. 10, 821-829 (1955) October.

The influence of chromium and copper additions on the elastic limit, tensile strength, elongation, fatigue and stress corrosion of a specific aluminum-zinc-magnesium alloy was experimentally investigated. The results obtained seem to indicate that the presence of chromium raises the elastic limits, increases tensile strength, diminishes elongation; as a general rule it favors the tendency to stress corrosion of the aged alloy, while for the alloy normalized at 180°C certain percentages, such as 0.14% and 0.57% chromium are particularly obnoxious. Resistance to fatigue varies slowly with increasing chromium contents and above 0.25% it remains stationary. The effect of copper on the static strength properties of an aluminum-zinc-magnesium alloy containing chromium is negligible. Added to the alloy containing 0.25% chromium, $\leq 25\%$ copper improves fatigue resistance. Also 0.25% copper appears to have a favorable effect on the resistance to stress corrosion especially in the region where the chromium content is about 0.57%. Detailed results are tabulated and several microphotographs presented.—ALL. 11477

6.4.2, 3.7.2

The Effects of Impurities on the Corrosion Resistance of Aluminium. (In German.) P. BRENNER, F. E. FALLER AND

E. HOFFLER. *Aluminium*, 32, Nos. 1, 2, 6-12, 64-70 (1956) January, February.

To test the effect of impurities on the corrosion resistance of aluminum small quantities of copper, silicon, iron and zinc were added to high purity aluminum, in the form of single or group alloying and thus 23 variants of alloys containing 99.5 percent aluminum were produced. The alloys thus obtained were extruded, rolled to strips and by the application of various heat treatments were further subdivided into groups with annealed, semi-hardened and homogenized condition. The tests performed consisted of immersion in stirred sodium chloride solution plus 1% hydrogen peroxide, of intermittent dipping in 3% sodium chloride solution and of weathering in industrial atmospheres. Strength and elongation values of the samples as a function of impurities and of the corrosive action are compared and analyzed. In the second part, the microscopic and macroscopic findings are analyzed and the dependence of the mode and extent of corrosion on the type of test and on the amount of impurities is established.—ALL. 11331

6.4.2, 3.7.3

Fusion Welding of 24S-T3 Aluminium Alloy. J. B. ARTHUR. *Welding J.*, 34, No. 11, 558s-569s (1955) November.

Main difficulty in fusion welding is due to broad thermal solidification range of 24S-T3 alloy (aluminum-4.5 copper-1.5 magnesium-0.5 manganese), and resultant loss of strength at parent metal/weld metal interface due to loss of solution heat treatment. Inert-gas-shielded tungsten-arc process has been used, in conjunction with high quench rate and minimum heat transfer into parent metal: metallurgical investigation (photomicrographs are given). Comparison of physical and mechanical properties of aluminum clad 24S-T3 welded by different processes or riveted; also comparison with other aluminum alloys.—BNF. 11303

6.4.2, 3.7.4

Some Observations on the Internal Friction of Polycrystalline Aluminium During the Early Stages of Creep. G. B. BROOK AND A. H. SULLY. *Acta Metallurgica*, 3, No. 5, 460-469 (1955) Sept.

Measurements of internal friction and X-ray observations have been made during the tensile creep at constant load of super- and commercial-purity aluminum wire at room temperature, 250 and 350°C. Results discussed quantitatively in terms of dislocations.—BNF. 11380

6.4.2, 3.8.4

Formation of Oxide Films on Aluminium Immersed in Nitric Acid. (In French.) J. PATRIE. *Rapports Presentes au Congres International de l'Aluminium*, Paris, June, 1954, Vol. II, 1955, 67-72. Available from R. Blanchard, 61 Rue de la Tombe-Issoire, Paris.

Conditions of formation of the films and nature of the reactions occurring.—BNF. 11188

6.4.2, 3.8.4, 3.7.3

Influence of the Surface State on the Corrosion of Aluminium. (In French.) PIERRE A. JACQUET. *Rapports Presentes au Congres International de l'Aluminium*, Paris, June, 1954, Vol. II, 1955, 7-22. Available from: R. Blanchard, 61 Rue de la Tombe-Issoire, Paris.

The tests undertaken with various commercial qualities of aluminum, cold worked

and annealed, are described in order to compare the superficial attack of mechanically and electrolytically polished specimens in contact with different media (salt spray, alkaline and acid solution). The progress of corrosion was observed with a microscope and in the case of alkaline solutions the discussions of the observations suggests that some of the results published in the literature should be revised as the part played by the initial surface condition has not been sufficiently considered by the authors. (auth.)—NSA. 11127

6.4.2, 5.4.5

Corrosion-Resistant Paint Finishes for Aluminium. HEINZ ANDERS. *Metalloberfläche*, Sec. B, 9, No. 6, 85-87 (1955).

A review of preliminary degreasing and cleaning procedures and of suitable priming and finishing coats (and methods of application) for paint, lacquer and stoving finishes on aluminum and its alloys.—MA. 11326

6.4.2, 8.9.5

Aluminium in Italian Naval Reconstruction. (In French.) R. STRUSS. *Rapports Presentes au Congres International de l'Aluminium*, Paris, June, 1954, Vol. II, 1955, 255-264. Available from: R. Blanchard, 61 rue de la Tombe-Issoire, Paris.

Before the war aluminum consumption reached 90 tons per ship; the more important merchant ships built or rebuilt today contain up to 200 tons of light alloys, mainly of the aluminum-magnesium type; properties and advantages of light alloys, economics and examples of application.—BNF. 11084

6.4.4

Forging and Die-Pressing of Magnesium-Alloys of the Magnesium-Aluminum-Zinc Type. (In German.) WILHELM ROSENKRANZ. *Z. Metallkunde*, 47, No. 2, 107-117 (1956) February.

The practical value of die-forging of magnesium-zinc alloys is said to depend 1) on the chemical composition of the alloy which should be such that obnoxious effects of the intermetallic compound Al_2Mg might be eliminated, 2) on the plastic flow properties of the metal and specifically on its resistance to flow; and finally 3) on the closest possible temperature control during subsequent forging stages in order to prevent recrystallization. In accordance with these considerations the initial material used for the production of die-forgings and the effect of the CCP casting temperature on their mechanical properties are analyzed. The functional interdependence of percent deformation, forging temperature, duration of pre-heating, duration of the sustained pressure and resulting grain size is discussed and the effect of the rate of deformation on grain size is investigated in a similar way. Further research work was done on stress corrosion of magnesium-aluminum-zinc forgings and on the effects of the various methods of heat treatment and quenching.—ALL. 11353

6.4.4, 5.9.4, 3.6.8

Quarterly Report No. 7 for the Period October 1, 1953, to December 1, 1954, Phase III. A Fundamental Study of Natural and Synthetic Films on Magnesium and Its Alloys. Dow Chemical Co. Metallurgical Labs., Midland, Michigan. Rept. 15719, 44 pp.

The microstructures of the corrosion films formed on magnesium as a result of exposure to sodium chloride-sodium chromate aqueous systems have been studied.

The polarization behavior of magnesium and magnesium alloys in salt-chromate solutions was determined. A hypothesis was advanced to explain the delay effect.—NSA. 11460

6.6 Non-Metallic Materials

6.6.4 Graphites: Oxidation Rates Established in Recent National Bureau of

Standards Studies. *Iron Age*, 175, No. 23, 115-117 (1955) June 9.

The establishment of a set of numerical constants for the oxidation rates of natural graphites in oxidizing atmospheres indicates that coarser sizes of graphites having a graphite content of about 85 percent are difficult to oxidize either in air or in a stream of oxygen at 400C. When fine and coarse sizes are combined as in finished and unglazed crucible bodies, a slow oxidation begins at 400C and the rate increases at higher

temperatures with a definite deterioration of the body.—NSA. 10429

6.6.5, 6.2.3

Wires Break in Prestressed Reservoir. *Eng. News-Record*, 154, No. 22, 27 (1955) June 2.

Prestressing cables, consisting of high-strength steel wires, were set in walls before concrete was placed and tensioned after concrete hardened. They were not grouted in, and five months later some were found corroded and

CORROSION ENGINEERING DIRECTORY

cathodic protection service



Eighteen cathodic protection engineers with a combined total of over 150 years experience available to serve you with ABILITY and INTEGRITY.

Houston, 4601 Stanford St.
BRANCH OFFICES

Tulsa • New Orleans • Corpus Christi • Denver

• Complete CATHODIC PROTECTION

Systems . . . service for special applications; water tanks and pipe lines.

HARCO CORPORATION

16901 Broadway Cleveland, Ohio

FRANCIS W. RINGER ASSOCIATES

• Consulting Corrosion Engineers

7 Hampden Ave. MOhawk 4-2863
NARBERTH (Suburb Phila.) PENN.

CATHODIC PROTECTION

Surveys • Designs • Engineering

Pipes Lines • Offshore Platforms
Refinery and Gasoline Plant Lines
Municipal Systems • Barges

CORROSION RECTIFYING CO.

1506 ZORA ST. PHONE UN 2-7522
HOUSTON, TEXAS

CORROSION ENGINEERING

SURVEYS • DESIGNS • SPECIFICATIONS

Impartial Evaluation

THE HINCHMAN CORPORATION

Engineers

Francis Palms Bldg., Detroit 1, Mich.



RIO Engineering Company

PROVED EXPERIENCE

In Installation, Field Survey, Design of Rectifier and Galvanic Anode Systems.

YOUR SHIELD AGAINST CORROSION

You Can Rely on Rio

3815 Garrot • Houston • JA 6-1259

Corrosion Control Systems

DESIGNED, INSTALLED, and MAINTAINED

Consultation on all types of metallic structures; corrosion surveys; designs; plans and specifications.

corrosion control inc.

823 So. Detroit • Tulsa • CH 2-7881

Cathodic Protective Systems Designed and Installed

Corrosion Surveys; Consultation On All Types of External Pipe Line Corrosion.

Huddleston Engineering Co.

Bartlesville Oklahoma

A. V. SMITH ENGINEERING CO.

CONSULTING ENGINEERS ON CORROSION PROBLEMS

Essex Bldg.
Narberth, Pa.

Mohawk 4-3900

CORROSION SERVICE LIMITED Offers in CANADA

A Complete Service in Corrosion Engineering Design and Installation of Cathodic Protection Systems.

Resistivity and Electrolysis Surveys Selection and Application of Protective Coatings.

21 King St. East, Toronto, Canada

D. MARKOFF ASSOCIATES

CORROSION CONTROL • ENGINEERING • CATHODIC PROTECTION
corrosion and electrolysis surveys
designs
plans and specifications
consulting and testing

P. O. BOX 541

HERMOSA BEACH, CALIF.

SOUTH FLORIDA TEST SERVICE

Testing—Inspection—Research—Engineers

Consultants and specialists in corrosion, weathering and sunlight testing.

4201 N.W. 7th St. • Miami 34, Florida

Corrosion Engineering

Surveys, Designs and Specifications
Construction Supervision

EBASCO SERVICES INCORPORATED

TWO RECTOR ST., NEW YORK 6, N. Y.

CHICAGO • DALLAS • PORTLAND, ORE. • WASHINGTON, D.C.

P E S C O

CORROSION ENGINEERING Consulting Surveys

CATHODIC PROTECTION

Design & Installation

Plastic Engineering & Sales Corp.
Box 1037 Ft. Worth, Tex.
WE 5680

WATER SERVICE LABORATORIES, INC.



Specialists in Water Treatment

Main Office, 423 W. 126 St., N. Y. 27, N. Y.

Electro Rust-Proofing Corp. Engineering Division

Corrosion Surveys
Cathodic Protection Design
Plans • Specifications
Electrolysis Control
Testing

BELLEVILLE 9, NEW JERSEY

Atlanta • Chicago • Dallas • Monrovia

Low Cost Advertising of Engineering Services

You can keep your name before those interested in corrosion engineering services in this directory at a nominal cost. Write today for advertising rates and other information about the merits of CORROSION. Advertising Dept., CORROSION, 1061 M & M Bldg., Houston 2, Texas.

broken. Original cable had to be replaced.—INCO. 10474

6.6.6

New Refractory Uses for Silicon Nitride Reported. J. F. COLLINS AND R. W. GERBY. *J. Metals* (Trans. AIME), 7, No. 5, Section 1, 612-615 (1955) May.

Methods of fabrication for refractory purposes; properties and comparison with other materials; behavior toward various corrosive media and toward molten metals; oxidation resistance; applications (mold washes for cast iron and steel, aspirator thermocouple assemblies, protecting tubes for thermocouples in molten aluminum.—BNF. 10513

6.6.7

Latex-Cements. E. G. RAWLINGS. *Corrosion Technology*, 2, No. 9, 278-283 (1955) Sept.; *Corrosion Prevention & Control*, 2, No. 11, 27-30 (1955) Nov.

Outlines methods of preparation of latex-cements, their unique properties and their applications in a number of industries including general chemical, breweries, soft drinks, sugar refining, effluent systems, fertilizers and detergents.—INCO. 11506

6.6.7, 6.6.8

Organic Corrosion. B. S. BIGGS. *Bell Labs Record*, 34, No. 1, 1-4 (1956) Jan. Discusses the detrimental effects of thermal- and photo-oxidation, erosion hydrolysis and ozone on rubber, plastics and other polymers. Tests such as outdoor exposure, accelerated laboratory aging and determination of oxygen absorption are described.—INCO. 11325

6.6.8, 1.7.1

Report on Rigid Polyvinyl Chloride. A Report of NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. R. MCFARLAND, JR., Chairman. *Corrosion*, 12, No. 4, 183t-186t (1956) April.

The development of rigid polyvinyl chloride has opened an entirely new field in structural applications. Rigid polyvinyl chloride has sufficient structural strength, impact resistance and hardness to replace metals in many forms. At the same time, polyvinyl chloride offers such inherent properties as extreme corrosion resistance, heat and electrical insulation, dimensional stability, low maintenance, ease of fabrication, lightweight and good aging.

Unplasticized vinyl chloride has exceptional resistance to acids, alkalis, alcohols and aliphatic hydrocarbons. The resin is non-oxidizing insoluble in most chemicals and self-extinguishing. The maintenance of these properties in the final product depends upon the modifiers used in specific formulations.

Recommendations are made regarding the use of rigid polyvinyl chloride in various media. Corrosives in which tests were made include three concentrations of sulfuric acid, three concentrations of hydrochloric acid, two concentrations of nitric acid, two concentrations of phosphoric acid, acetic and glacial acetic acid, fatty acids, hydrogen peroxide, sodium hypochlorite, chromic acid, two concentrations of sodium hydroxide, potassium hydroxide, water, five salts, three fats and oils and nine solvents. Mechanical properties are given for Type I and Type III polyvinyl chloride.

Fabrication of rigid polyvinyl chloride is discussed in detail. Topics considered in this connection include machining methods, molding techniques and joining techniques. 11197

6.6.8, 2.3.7, 7.2, 7.5.5

Status Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. B. W. BRADLEY, chairman. *Corrosion*, 12, No. 6, 69-72 (1956) June.

Mandel wound glass-plastic pipe has a tendency to develop slow weeping type leaks at pressures far below those which ordinarily would cause failure by rupture. It was thought that poor glass-resin bond might be responsible for such leaks. To test this theory and to supplement direct microscopic examination by a more positive method of measuring bonding improvement, edgewise porosity tests for pipe and flat laminates were advised. An account is given of the procedure followed in making these tests and of the results obtained.

Circumferential measurements were made to determine creep on a 250-barrel glass mat reinforced polyester oil field stock tank. A comparison of empty and full measurements during the second and third summers showed little difference. Similar measurements were made on a 250-barrel glass fiber reinforced epoxy oil field stock tank. It was found that less circumferential difference occurred between the second summer and winter than during the first year. Summer measurements will be made until such time as no more creep is indicated.

Results of high pressure field tests on glass reinforced plastic pipe and tubing are reported in detail. 11397

6.6.8, 7.5.5

Status Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. B. W. BRADLEY, chairman. *Corrosion*, 12, No. 3, 73-76 (1956) Mar.

Long term strength of cellulose acetate butyrate is discussed. The strength of the material had been reported previously to be near 800 psi at about 100F. Recently another investigator found the value to be around 400 psi by a similar test. Reasons for the difference are discussed and explained by the company making the first report.

A report on service experience of plastic tanks is given. This supplements a report on this subject published in 1955. Cracking type failure is believed to result from eccentric loading that comes from filling and emptying the tank. The cracks generate from irregularities or wrinkles in the glass. If the theory is true, cracking type failure can occur with tanks fabricated from any resin system and probably can be eliminated only by careful glass handling and control by the tank fabricator. 11149

6.7 Duplex Materials

6.7.2

Cermets. J. R. BAXTER. *Australasian Engr.*, 46, 45-50 (1955) September.

Reviews German war-time work and the post-war research in USA and UK (carbide, boride, silicate and oxide based cermets). Properties, bonding, structure, etc. 24 references.—BNF. 11298

6.7.2, 1.6

Study of the Systems TiC-SiC-B₂C and TiC-VC-ZrC. OLIVER E. ACCOUNTIUS, ROBERT F. STOPS, HOWARD E. KONRAD, HAROLD M. GREENHOUSE AND CLINTON MCBRIDE. Ohio State Univ. Research Foundation. U. S. Wright Air Develop-

ment Center, Tech. Report 53-287, March, 1955, 200 pp.

The initial study of the density and oxidation resistance of 66 binary and ternary compositions in the system TiC-SiC-B₂C is given. A dense oxidation-resistant area, attributed to the formation of a complex borosilicate glass, was found in the triaxial diagram. Characteristics of both hot-pressed and sintered compacts are investigated. The oxidation mechanism in two commercial mixed-carbide base cermets is studied. An hypothesis is presented to explain and a parameter is derived to measure the relative oxidation resistance of mixed carbides and carbide base cermets. The metal bonding of the most promising compositions suggested by the triaxial diagram are treated. Of special interest was the system 55.4 TiC+17.9 TiB₂+10.0 Si+16.7 Co. Some of the physical properties of binary and ternary compositions in the system TiC-VC-ZrC are also investigated.—NSA. 11373

6.7.2, 8.8.5

Chrome Carbide for Hot Extrusion of Brass and Copper. A. E. GLEN. *Wire and Wire Products*, 30, No. 10, 1230-1231, 1294 (1955) October.

Use of chromium carbide (83Cr₇C₃/2WC/15Ni) for extrusion dies for copper or brass tubes and rods. Physical and mechanical properties of die material; corrosion resistance; mounting and finishing of die. Among advantages claimed are ability of chromium carbide to maintain size during use and to withstand high extrusion pressures and to produce better quality extrusions.—BNF. 11405

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

Light Metal Bearings and Their Uses. (In French.) A. BUSKE. *Rapports Presentes au Congres International de l'Aluminium*, Paris, June, 1954, Vol. II, 1955, 305-314. Available from: R. Blanchard, 61 Rue de la Tombe-Issoire, Paris.

Advantages in cost, weight, ease of working, high thermal conductivity and fairly low elastic modulus; a common practice is to mount light alloy bearings in light alloy housings to avoid trouble with differences in expansion. Certain thin bearings are coated on steel, etc., sheet (Al-Fin process).—BNF. 11125

7.1

A Guide to Bearing and Bushing Choice. J. B. MOHLER. *Steel*, 137, Nos. 5, 6, 76-78, 88-89 (1955) August 1, August 8.

Bearing properties to be considered are wear resistance, yield strength, corrosion resistance, high-speed performance, conformability, ability to seat and seizure resistance. Load capacities of steel-backed bearings for internal combustion engines and for electric motor bearings of aluminum, copper-lead, lead bronze and Babbitt are compared. Tables.—INCO. 10604

7.1

Large Ball Bearings. L. JONES, JR. *Product Eng.*, 26, No. 10, 156-160 (1955) October.

Reviews basic types of large diameter (6-inch and over) radial and thrust bearings and separators, effect of speed and number and size of balls on capacity, selection of bearing material and

-287, March,
density and
binary and
system TiC-
oxidation-re-
formation of
was found
characteristics
of compacts are
mechanism in
the base cer-
is presented
is derived to
in resistance
the base cer-
of the most
tested by the
Of special
TiC + 179
some of the
and ternary
TiC-VC-ZrC
11373

tolerances. SAE 52100 high-carbon high-chromium is used for bearings of conventional design. For extreme corrosion conditions, 400 series stainless steel, K Monel or S Monel are used. Tables, diagrams.—INCO. 10797

7.1 Antidotes for Sleeve Bearing Failures. A. F. KAMINSKAS. *Iron Steel Engr.*, 32, No. 10, 82-89; disc., 89 (1955) October. Bearing failures are classified as fatigue, wiping and seizure, corrosion, wear and scoring and erosion. Actual failures are more specifically attributed to insufficient clearance, poor alignment, dirt in oil, overloading and high temperature. Good design and maintenance are discussed as antidotes against failures. Examples are shown of failures due to combination of fatigue and corrosion and to fretting corrosion, as well as other forms of failure. Graphs.—INCO. 10802

extrusion of
N. Wire and
0-1231, 1294
(83Cr₃C₃)
es for cop-
physical and
e material;
and finish-
claimed are
to maintain
and high ex-
duce better
11405

7.1 Teflon-Impregnated Bearings for Service in Water. H. B. NUDELMAN AND CORD H. SUMP. Armour Research Foundation, Chicago. *Metal Progress*, 68, No. 2, 112-113 (1955) Aug. It has been found that porous stainless steel bearings can be used, when water must be used as the lubricant, by impregnating the bearings with Teflon.—NSA. 10838

7.1 Lifters and Lubricants. J. B. BIDWELL AND P. VERMAIRE. Paper before Soc. Automotive Engrs., Nat. Passenger-Car, Body, and Materials Mtg., Detroit, March 2, 1954. *Trans. SAE*, 63, 211-220 (1955). Discusses relationship of the factors of lubricant and engine design which affect wear of cams, lifters, rocker arms and rocker shafts. Laboratory tests show that particular additives lack boundary lubricant properties and promote lifter pitting. Chilled cast iron, hardened cast alloy iron and carburized steel are evaluated as lifter materials with respect to their ability to operate with poor lubricants and under adverse conditions. Carburized steel lifters suffered the most damage due to pitting, scuffing and wear. Corrosion fatigue is discussed as the cause of accelerated lifter pitting.—INCO. 10869

Their Uses.
reports Prel-
al de l'Alu-
II, 1955.
anarch, 61
s.
at, ease of
activity and
a common
y bearings
oid trouble
n. Certain
l, etc., sheet
11125

7.1, 3.5.9, 1.7.1 Research Is Many Things. H. A. LIEBHAFSKY, H. H. MARVIN AND E. L. SIMONS. Paper before Gen. Elec. Phys. Chem. Sect., Schenectady, March, 1954. *Gen. Elec. Rev.*, 58, No. 4, 14-17 (1955) July. Review of how the Physical Chemistry Section at General Electric tackled the problem of corrosion difficulties experienced with power plant and locomotive gas turbines that burned residual fuel oils. Effects of vanadium pentoxide, sulfur and sodium were investigated. Chemical analysis of ash deposits in first stage nozzle of gas turbine showed principal components to be sodium and calcium sulfate; color of ash is produced by oxides of vanadium, iron, nickel and chromium. Heating such deposits at 1300-1850°F produced hard, heterogeneous scale caused by melting behavior of sodium and calcium sulfates and insolubility of metal oxides in resulting liquid phase. Undesirable consequences are heavy deposit build-up and corrosion under cycling-reducing and oxidizing conditions of alloy steels. Reaction of

vanadium pentoxide with Type 310 is summarized and results indicate that stainless steel is corroded by sulfides with vanadium pentoxide serving as oxygen source and carrier.—INCO. 10439

7.1, 7.2 Running Diesel Engines on Boiler Fuel: Corrosion Resistant Valves Needed. *Engineering*, 179, 384 (1955) March 25.

Short account of tests on use of boiler oils in Diesel engines at Mirreles, Bickerton and Day, Ltd. Successful operation was achieved. In earlier tests, serious trouble was encountered with En 54 (nickel-chromium-tungsten) steel exhaust valve seating faces. This took form of "wire-drawing" or "gutting," followed by gas blow-by and burning: standard valves of En 54 were burnt out in 50 hours or less. Trouble was due to action of fuel ash deposits: probable formation of vanadium pentoxide. Bright-ray coatings proved most effective and company has now decided to standardize on En 52 (silicon-chromium) steel coated with Bright-ray for all K-class units. When boiler oil is used, valves must be cleaned and resealed every 500 hours.—INCO. 10787

7.1, 5.11, 3.5.3 How Can We Prevent Steam Turbine Erosion and Corrosion? F. H. PENNELL. *Power Eng.*, 60, 100-101 (1956) Jan.

Better resistance to corrosion and erosion may be effected by design improvements and by improving the surface of the blade. Diagrams, photographs.—BTR. 11348

7.2 Valves, Pipes and Meters

7.2, 6.6.8 Plastic Pipe in Chemical Processing Industries. B. W. BENDER AND J. W. HAWLEY. *J. Soc. Plastics Engrs.*, 11, No. 1, 16-18, 54 (1955) Jan.

Plastic pipe is valuable for piping through highly corrosive atmospheres, for conveying corrosive fluids and for handling deionized and demineralized water and sensitive chemical solutions without contamination. Types and materials employed, available sizes and fittings and representative applications are given.—BL. 11297

7.3 Pumps, Compressors, Propellers and Impellers

7.3 Stratocruiser Ditched When Engine Fails: CAB Report on Pan American B377 Crash off Oregon. *Aviation Week*, 64, No. 1, 45-48, 51-54 (1956) Jan. 2.

Vibration which occurred immediately before No. 3 engine wrenched free followed a familiar pattern of known propeller blade failures. Most recent modification was to nickel-plate blade surface to minimize service-incurred nicks and gouges. Blades on PAWA fleet of B-377 aircraft were nickel-plated and maintained according to manufacturer's instructions. Intensive inspection program revealed three cracked model 2J17 blades that were associated with corrosion and one blade failed from corrosion while undergoing fatigue testing at factory. Corrosion which is known often to serve as foci for fatigue failure was found on 13.5% of the PAWA-Pacific-Alaska Division blades.—INCO. 11299

7.4 Heat Exchangers

7.4.1 Blockage and Corrosion of Plate and Tubular Recuperative Air Heaters. B. LEES. *J. Inst. Fuels*, 28, 433-440, 450 (1955) Sept.

New method of investigating air-heater corrosion; measures adopted to overcome corrosion and blockage of some tubular and plate-type air heaters. Tables, diagrams, graphs, photographs. 12 references.—MR. 11438

7.4.1, 1.4, 4.6.4, 5.8.2 Corrosion in Engine Cooling Systems Containing Aluminium: A Literature Survey. MILDRED BENTON, compiler. Naval Research Laboratory, Washington, D. C., Bibliography No. 5, 1955, 31 pp.

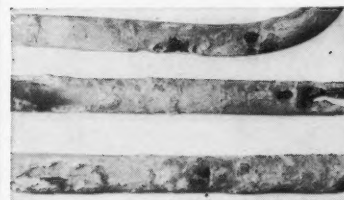
Bibliography covered the period, 1926 to 1955 and was based on an investigation of other systems using aluminum-containing structures for cooling and inhibitors used for such systems.—BTR. 11310

7.4.1, 6.3.6 Condenser and Preheater Corrosion. (In German.) W. KATZ. *Brennstoff-Warme-Kraft*, 7, No. 10, 439-445 (1955) October.

Corrosion phenomena on copper occurring in connected condensers and preheaters; materials and its selection; suggestions for preventive measures. Graphs, photographs, table. 7 references.—BTR. 11452

7.4.2, 6.3.6 The Significance of Apparently Minor Factors in Corrosion Problems Affecting

CORROSION PROBLEMS?



SULFUR, VANADIUM, AND SODIUM, FROM THE FUEL OIL CAUSED THESE BOILER TUBE FAILURES

BARSAD FUEL TREATMENT PREVENTS THIS CORROSION

THIS MAY BE THE TREATMENT YOU NEED

BARSAD

T.M. Reg. U.S. Pat. Off.
Pat. Pending

FOR DETAILS WRITE
R. S. Norris & Associates
LARCHMONT, N. Y.

1 Bushing
37, Nos. 5,
st 1, Au-
considered
length, cor-
perform-
o seat and
capacities of
ernal com-
etric motor
-lead, lead
ed. Tables.
10604

JONES, JR.
160 (1955)
large diam-
and thrust
t of speed
on capac-
terial and

Condenser and Cooler Tubes. C. BRECKON AND J. R. T. BAINES. *Trans. Inst. Marine Engrs.*, 67, No. 10, 363-372 (1955) Oct.

Notes on various aspects of corrosion problems encountered in service with brass and copper-nickel condenser tubes: dezincification of brasses; erosion-corrosion; effects of composition in relation to erosion-corrosion; influence of cupro-nickel alloys; effects of iron content on behavior of 90/10 cupro-nickel; season-cracking; effects of obstruction in tubes on corrosion behavior; and effect of position in condenser on corrosion behavior. There are also a number of apparently minor factors which can have an important bearing on results obtained.—INCO. 11317

7.5 Containers

7.5.5, 5.2.2

An Application of Cathodic Protection to the Inside of a Tank. J. H. GRAVES. *Corrosion*, 12, No. 5, 254t-256t (1956) May.

A 10,000 barrel bolted tank was found to have developed active internal corrosion within an eight year period. The tank was then coated on inside bottom and two feet upon the shell with a coal tar product and steam coils were installed. After 12 years' additional service it was found that four leaks had developed in the tank. It was again cleaned, the steam coils removed, and the tank visually inspected. Welded repairs were made to the tank and the coating was repaired. Four 9 pound magnesium anodes were installed at this time and 6 inches of water was placed in the tank to serve as electrolyte. Anodes were installed so that they could be inspected or replaced while the tank was in service; records were made of anode outputs, driving potential, anode efficiency and tank-to-

electrolyte potential. Current outputs were restricted and the 9 pound anodes ultimately were replaced with 17 pound anodes.

A measured output of 666 ampere-hours/pound was obtained from one of the 9 pound anodes. It is calculated that four 17 pound anodes would last 3 to 4 years, with more than ample current when restricted with a 1 ohm resistor. Tank to electrolyte potential at the last reading measured —0.4 volts to iron reference electrode. 11261

7.6 Unit Process Equipment

7.6.4

Corrosion Problems in Small Heating Boilers. H. F. HINST. *J. Am. Water Works Assoc.*, 48, 11-18 (1956) Jan.

Causes and prevention of corrosion in low-pressure heating boilers. Graphs, photographs, micrographs.—BTR. 11346

7.6.4, 3.5.2

Boiler Waterside Deposits. F. E. CLARKE. *Bureau of Ships J.*, 4, 23-26 (1955) May.

The regular inspection of boiler watersides and the correct interpretation of the conditions observed are an essential part of boiler care. By careful examination a boiler operator can usually distinguish between harmful scale and normal sludge deposits. He can also recognize evidence of faulty blowdown, oil contamination, overheating and corrosion. A partial inspection can be made in the drums and headers, but for an accurate analysis of waterside conditions a sample tube should be removed and split. Descriptions of boiler waterside deposits to aid in making the most of boiler inspection are given.—TIME. 11389

7.6.4, 5.2.2, 5.4.5

An Evaluation of Organic Coatings for Use in Cathodically Protected Domestic Hot-Water Tanks. B. G. BRAND, F. W. FINK, G. A. HUDSON AND E. R. MUELLER. *Paint and Varnish Production*, 46, 25-32 (1956) January.

Organic coatings used on domestic hot-water tanks, protected with magnesium anodes, must have alkali resistance and water impermeability. Epoxy-phenolic resins appear to be the solution. Graphs, diagram, photograph, tables. 4 references.—MR. 11336

7.6.6

The Identification of Digester Corrosion Conditions and Methods for Their Prevention. L. A. DELA GRANGE. Paper before TAPPI, 9th Eng. Confer., Philadelphia, October 18-21, 1954. *Tappi*, 38, No. 6, 347-352 (1955) June.

Information obtained from experiments on 45 digesters. Types of metal loss including light pitting, grooving or channeling, grooving below fittings; effect of liquor washing and impingement; and reduction of metal loss by use of deflector bands, redesign of circulating liquor nozzle, Type 310 stainless overlay and elemental sulfur to prevent overall corrosion are discussed. Graph, illustrations.—INCO. 10505

7.7 Electrical—

Telephone and Radio

7.7, 3.6.6

Underground Corrosion on Rural Electric Distribution Lines. O. W. ZASTROW. Paper before Am. Inst. Elec. Engrs., Winter Gen. Mtg., New York, January 31-February 4, 1955. *Trans. Am. Inst. Elec. Engrs.* (Applications and Industry), No. 18, 101-108; disc., 108-109 (1955) May.

Anchor-rod corrosion on multigrounded distribution lines occurs as a result of galvanic action between copper-covered ground electrodes and galvanized steel anchor rods connected to system neutral through uninsulated guys. Three general types of preventive measures are: insulation of buried steel anchor rods from copper-grounded neutral or replacement of steel components with other materials that will not corrode excessively when connected to copper-grounded neutral, replacement of copper ground electrodes with galvanized-steel ground rods and installation of galvanic anodes to provide drainage and to prevent damage to anchor rods or other buried structures.—INCO. 11059

7.7, 5.3.1, 5.4.1

Surface Treatment in Electrotechnics with Special Reference to Telecommunications. (In German.) K. LEICH. *Metall*, 9, No. 11/12, 478-482 (1955) June.

Formation of coatings: metallic coatings (nickel, zinc, copper, chromium, tin, aluminum, noble metals, coatings on insulators); inorganic non-metallic coatings; organic coatings (oils, fats, lacquers). 34 references.—BNF. 10902

7.7

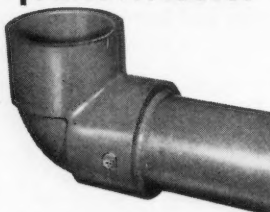
Materials for Valves. R. O. JENKINS and others. *J. Inst. Elect. Engrs.*, 1, No. 9, 564-565 (1955) Sept.

Summary of discussion held March 21st, 1955, by the Radio Section of the Institution. Materials for cathodes and heaters, grids and other electrodes, envelopes (including seals), miscellaneous uses. Metals mentioned included nickel, tungsten, molyb-



Makes stronger joints...faster in PVC PIPING

Here is a team for improving your PVC piping: (1) Tube Turns Plastics' socket type PVC fittings and (2) "ttp" Solvent Cement. The combination gives joints as strong or stronger than the pipe itself. Fittings are injection molded by exclusive Hendry process. Cement is simple to apply with a paint brush as



shown. For complete details on "ttp" socket and threaded types PVC fittings and flanges, and on "ttp" solvent cement, write Tube Turns Plastics, Inc., Dept. PG-11, 2929 Magazine St., Louisville 11, Kentucky.

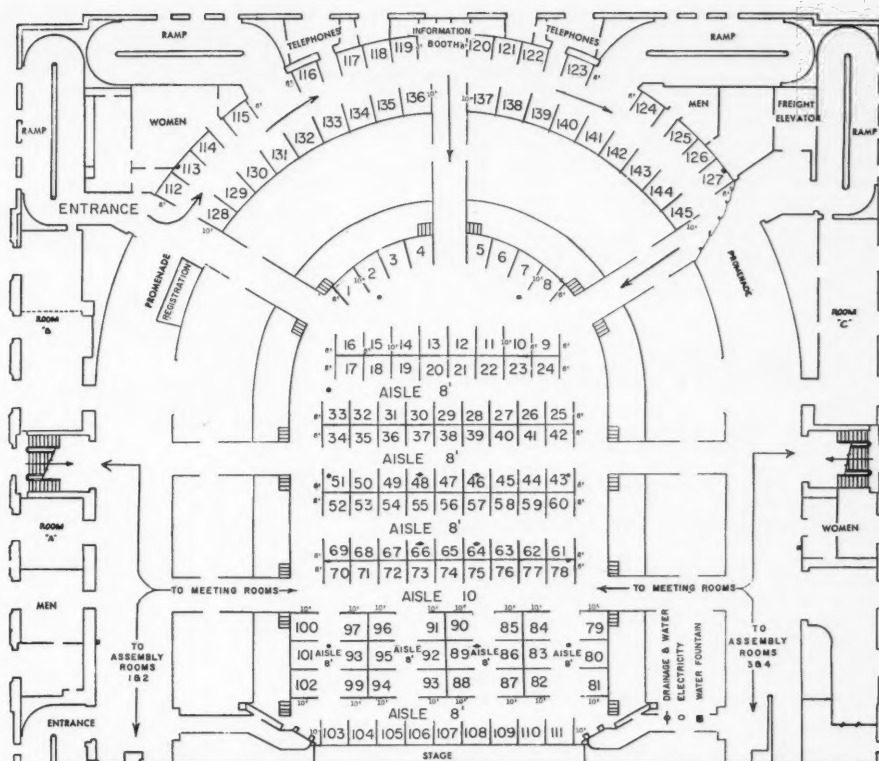


TUBE TURNS PLASTICS, INC.

Louisville 11, Kentucky

Call your TUBE TURNS PLASTICS' Distributor

13th
NACE
 Conference
 and
 Exhibition
 •
KIEL
 Auditorium
 St. Louis
 Mar. 11-15
 1957



Will YOUR PRODUCTS be shown here?

Some Advantages of NACE Exhibition

- You get to talk to the men who are really interested in your products because they need them in their work.
- You get the advantage of the concentrated interest on corrosion prevention that is found only at NACE Conferences.
- You participate in an exhibit arranged to give you the best break on location, competition and exhibit times.
- You avoid the lost motion involved in answering the questions of curiosity seekers who are not real prospects.
- Technical meetings in the same building help to increase traffic on the exhibit floor.
- You get experienced help in setting up and taking down your exhibit at St. Louis which is convenient to everywhere.

The NACE Exhibition is certainly the best opportunity during the year to show your products and explain your services to a group of men who have the authority to do something about corrosion control. If your company has not already contracted for booth space at this display of corrosion resistant materials, products and methods of mitigation, be sure not to overlook the opportunity you have NOW to do so. Cost of space is reasonable. Complete information is available now.

**You Owe it to Yourself and Your Company
 To Investigate the Advantages of this Exhibition**

**Write Today for Descriptive
 Literature and Contracts to**

A. B. Campbell, Executive Secretary

National Association of Corrosion Engineers

1061 M & M Bldg. • Houston 2, Texas

Act Today While There Are Choice Locations

denum, aluminum-clad iron, molybdenumtungsten, nickel-manganese, Dumet (copper-coated nickel-iron), chromium-nickel-iron, OFHC copper, barium, zirconium, etc.—BNF. 11436

7.7, 3.6.2, 3.6.6, 6.3.8

Cell Corrosion on Lead Cable Sheaths. Third Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths by Task Group T-4B-1 on Corrosion of Lead and Other Metallic Sheaths. T. J. Maitland, Chairman. *Corrosion*, 12, No. 5, 257t-259t (1956) May.

Action in a concentration cell is described briefly and shown in an accompanying diagram. A case involving attack on lead cable sheath by differential aeration cell action is described. The center portion of the cable was not attacked because it was pressed tightly against the inner surface of the tile duct. During the time the cable was in this position, water of varying amounts formed a meniscus extending from the sheath surface to the tile and reaching all the way around the dry area. Immediately outside of the area pressed against the tile, the lead had been removed by anodic action.

A case involving galvanic corrosion of a lead telephone cable sheath is discussed. It was found that the moisture seal over the lead and steel had been destroyed exposing the metal coverings to attack by electrolytes of the soil. The effect of pH on polarity of lead and iron in a common electrolyte is shown in a diagram. 11263

7.7, 6.6.5, 6.3.8

Preventing Corrosion of Lead Sheathed Power Cables in Concrete Tunnels. R. I. PERRY. *Corrosion*, 12, No. 5, 207t-212t (1956) May.

An appreciable amount of corrosion was found to exist on the lead sheaths of underground power cables where these cables were located in concrete tunnels. The corrosion occurred at several locations in a metropolitan city where the lead sheathed cables were installed in continuous, precast concrete ducts and in ducts of other non-metallic materials encased in concrete and placed in concrete tunnels under waterways. Tests indicated that the corrosion on the lead sheathed cables was caused by calcium hydroxide from incompletely cured concrete.

Typical chemical analyses are shown of water from the continuous ducts. The sheath voltages and water conditions under which these cables operated are given and the methods employed to reduce the concentrations of calcium hydroxide in the continuous ducts are described. The pH values and concentrations of calcium hydroxide are shown for the water in the conduits in two tunnels prior to and after corrective measures were taken.

The methods now used by this company to cure concrete in tunnels before lead sheathed power cables are installed are described. A brief description is given of the prelubrication of continuous tunnel ducts before pulling in large cables. Corrosion is reduced by the application of pulling grease to the cables at the time of installation. 11271

7.7, 8.10.3

Positive-Polarity Grounding of Direct Current Supply Requirements in Mining Traction Systems. SIDNEY A. GIBSON. *Corrosion*, 12, No. 3, 119t-122t (1956) March.

Serious corrosion of mine traction systems using positive-polarity grounding of direct current supply equipment is described. Abnormally increased costs from excessive trolley insulator failures and a

safety hazard resulting from possible formation of pure metallic sodium or potassium in corrosion products are reported.

As a consequence of these conditions, Tennessee Coal and Iron Division of U. S. Steel Corp. has converted the only two of its mines in which the traction systems were designed for positive-polarity grounding of negative-polarity trolleys.

Reasons for the installation in mines of positive-polarity systems are given. Illustrations show how the corrosive electrolysis destroys the rock in which trolley supports are fastened.

Tests indicate the presence of pure sodium or potassium in corrosion products. These metals will cause skinburns and when bits of the crusty deposit formed on the insulator fell into pools of water on the mine floor an explosive reaction accompanied by flame occurred.

Extent of possible economic effects of these corrosive reactions on the mine transport systems are given. 11201

8. INDUSTRIES

8.1 Group 1

8.1.2, 5.11

The Design of Buildings for Corrosive Conditions. C. H. TOPPING. Paper before Corrosion Symposium, Montreal, Sept. 15, 1955. *Can. Chem. Processing*, 39, No. 11, 31-34, 36 (1955) Oct.

Lists the danger points for corrosion, design considerations and possible preventive measures in foundation, roofing and walls of an industrial building subjected to corrosion conditions of varying severity.—INCO. 10992

8.1.4, 4.6.13

Methods of Preventing Corrosion in Sewerage Systems. ERVIN SPINDEL. *Corrosion*, 12, No. 3, 136t-140t (1956) March.

Means of preventing deterioration of structures handling sewage or exposed to the fumes from sewage are discussed. Relative merits and application techniques of chemical additives are considered. Recommendations concerning control through design to increase velocity or eliminate vapor space are weighed. Application of and results achieved through ventilation of sewers are reported in some detail, including service results on installations over periods up to 16 years.

Control through use of materials resistant to the corrosives in sewage is outlined. Special cements, clay and plastic liners, special jointing materials and protective coatings for metallic and non-metallic materials at treatment plants are mentioned. Cathodic protection as an effective control measure is considered and recommended where feasible. 11151

8.2 Group 2

8.2.2, 5.2.1, 4.6.11

Cathodic Protection Cuts Repairs. J. B. PRIME. *Electrical World*, 144, 104-106 (1955) December 12.

Successful application to structures and equipment in generating plants that use salt water for condensing. Diagrams, photographs.—BTR. 11498

8.2.2, 7.6.4

Corrosion and the Modern Power Station. E. C. POTTER. *Research*, 8, No. 12, 450-455 (1955) Dec.

Problem and cost of corrosion in

steam boilers, with particular reference to power station industry. Embrittlement corrosion at high pressure is discussed. Photomicrographs compare metal-magnetite interfaces of mild steel generator tube operating at 675 lb./in.² and of one operating at 1420 lb./in.². By 1960, due to increasingly higher pressure and temperatures, incidence of boiler corrosion is expected to double. Research programs involving large scale trials in power stations, pilot plant experiments and fundamental studies are considered. Author suggests that power industry sponsor research on ionic equilibria in high temperature water.—INCO. 10961

8.3 Group 3

8.3.1, 8.8.1

Production and Use of Liquid Fertilizers. A. V. SLACK. *J. Agric. & Food Chem.*, 3, No. 7, 568-574 (1955) July.

One of the biggest problems is corrosive nature of liquid fertilizer as compared to dry products. For specific pieces of equipment, the reported general practice is to use rubber-lined steel or stainless steel for acid storage and handling, aluminum for ammoniating solution storage and handling, stainless steel for the reactor and ordinary steel or wood for finished storage.—INCO. 11014

8.3.2

Some Aspects of Canning Soft Drinks. H. T. JOHNSON, A. W. McALPIN AND A. M. SCHENCK. *Food Technol.*, 9, 643-647 (1955) Dec.

Factors adversely affecting shelf life are considered and development of a "Corrosivity Tester" is discussed. Graphs, table.—BTR. 11454

8.3.3

Aluminium in the Dairy Industry. Aluminium Labs. Dev. Bull., August, 1955, 33 pp. Aluminium Laboratories, Banbury.

Application of aluminum and alloys in milking machinery and equipment, dairy buildings and fittings, milk churns, milk storage tanks, pasteurizing equipment, bottle capping, delivery vans, packaging, road and rail vehicles and tankers, etc., including appendix on cleaning and sterilizing aluminum equipment: 0.5-5.0% sodium carbonate plus 0.05-1% sodium silicate is recommended and sterilization with dilute chlorine solution or chloramine-T.—BNF. 11351

8.4 Group 4

8.4.1

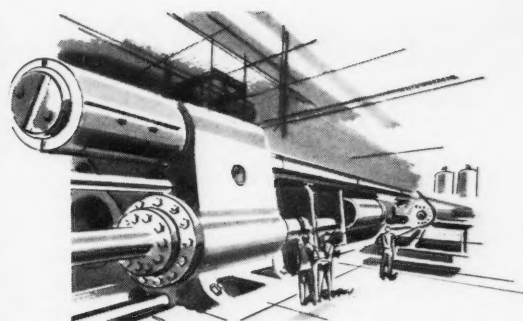
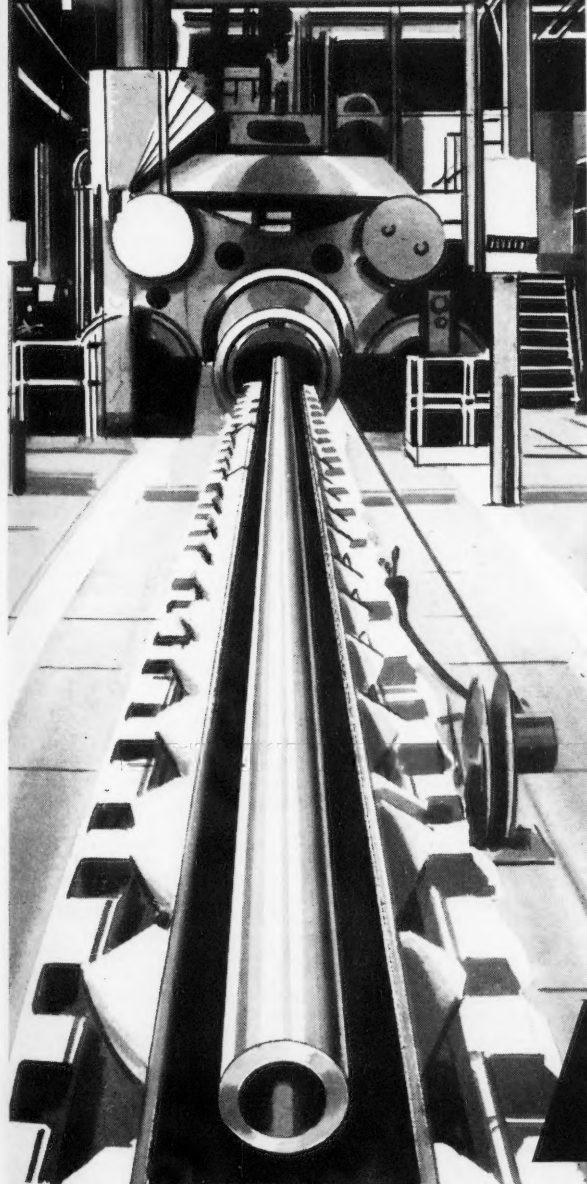
Corrosion of Galvanized Steel Coke Hods and Buckets. J. H. MORGAN. *Corrosion Technology*, 2, No. 9, 297-298 (1955) Sept.

Rapid internal corrosion of lower parts of galvanized steel bucket or hod used to carry and store coke is caused by electrolytic action between coke and galvanized steel. Experiments to determine the resistance between pieces of coke and a metal plate are described. Use of bituminous paint has achieved greater success than covering bottom of buckets with cardboard layer. Graphs, diagrams.—INCO. 10916

8.4.2, 8.4.3

How to Select Equipment to Prevent

For longer life, higher performance in the petroleum, chemical and power industries




Corrosion-Resistant, Heat-Resistant EXTRUDED Steel Pipe

Curtiss-Wright's Metals Processing Division now offers the petroleum, petrochemical and power industries a line of high-quality, extruded steel tubular products to meet the most severe demands of modern processing. Inherent corrosion and heat-resistant properties of the steel alloys used are amplified by extrusion because the finished tube is produced with only one heat, in one pass of the giant 12,000 ton press . . . formed under compression in a matter of seconds without seams, in lengths up to 50 feet. Extra margins of resistance to corrosion and heat are built in easily by extruding heavier pipe wall thicknesses at no sacrifice in production speed. The most up-to-date quality control facilities, including ULTRASONIC TESTING, are employed in production.

Curtiss-Wright's extrusion facility is a specialty mill, ideally equipped for the production of special purpose, premium quality tubing. Conformance to A.S.T.M. specifications and other exacting standards is assured by an experienced engineering staff and the most modern metallurgical testing equipment.

When higher pressures and temperatures, or more corrosive service conditions demand more than the ordinary in large diameter pipe, let Curtiss-Wright serve you through the nearest Metals Processing Division Branch Office, or write to the Main Office address shown below.

86 Grider Street, Buffalo, New York

METALS PROCESSING DIVISION
CURTISS-WRIGHT 
CORPORATION • BUFFALO, NEW YORK

ELECTRONICS • NUCLEONICS • PLASTICS • METALLURGY • ULTRASONICS • AVIATION

Solution Carryover, Remove Accumulated Sludge, Provide for Regeneration in Gas Purification Units. N. C. UPDEGRAFF. Girdler Company. *Petroleum Processing*, 10, No. 9, 1396-1399 (1955) Sept.

In Girbotol process, based on reaction of hydrogen sulfide and carbon dioxide with amines, equipment is built entirely of iron and steel, since amine solutions dissolve copper and brass and most alloys containing copper or zinc. Stress corrosion cracking in absorbers is avoided by good fabrication techniques followed by thermal stress relief. Gunit concrete linings and stoneware packing eliminate corrosion problems in reactivers. Frequency of heat exchanger tube corrosion is not great enough to warrant use of alloy tubes. Stainless steel is used for control valves and other critical parts, especially those subject to erosion by iron sulfide sludge.—INCO. 10991

8.4.3, 7.5.5

Why Did Those Storage Vessels Fail? F. L. RESEN. *Oil Gas J.*, 54, No. 25, 89-94 (1955) October 24.

Detailed metallurgical study at Baytown refinery of Humble Oil & Refining Company of regenerated catalyst hopper and spent catalyst vessels of fluid catalytic cracking unit. Material used in regenerated catalyst hopper was Type 304 and welding was done with Type 304 electrodes. Spent catalyst hopper and stripper were of Type 347. Data obtained from reduced section tensile, bend, Charpy impact, hardness and Strauss tests and metallographic examination of plate and weld specimens are given. In the Type 304 specimens cracks were invariably located in areas demonstrating severe plastic flow manifested by bulging, wrinkling, corrugating or similar distortion. Metal temperatures of 1500 F or greater result in carburization of inside surface, intergranular oxidation of outside surface and severe distortion. Strauss tests indicated susceptibility to intergranular corrosion. In the Type 347 material, failure was by intergranular cracking in areas of highest stress (due to sulfurous and sulfuric acid formation by hydrolysis of iron and nickel sulfide scale). Tables, photomicrographs.—INCO. 10949

8.4.2, 6.2.3

The Protection of Structural Steel. The Preservation of Steel on Gas Works. (Great Britain.) L. A. RAVALL. *Chemistry & Industry*, No. 48, 1526-1535 (1955) November 26.

Removal of millscale and metallizing in the pretreatment of steel; metal coatings and paint systems as protective methods. Table. 15 references.—BTR. 11502

8.4.3

Current Status of Corrosion Mitigation Knowledge on Sweet Oil Wells. A Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion. H. E. GREENWELL, chairman. *Corrosion*, 11, No. 10, 61-63 (1955) Oct.

Corrosion in high pressure flowing oil wells is becoming increasingly common. Methods currently used to limit corrosion damage include coated tubing, inhibitors and alloy tubing, with tubing coated with baked-on phenolics being favored most. Epoxies are being tested as a tubing coating.

Lack of success with weighted inhibitor sticks is reported but some operators are pushing sticks to bottoms with wire tools. Bottom hole injection is being tried by some but because of gelling of diluents in

wells with high bottom hole temperatures, caution in selecting diluents is advised. Results on use of alloy tubing are inconclusive.

Laboratory work on duplicating the conditions noted with respect to sparingly soluble sulfate scales has met with considerable success. A technique for preparing artificial scale is reported. A theory covering the reason for the porosity of the scale is advanced.

In connection with corrosion believed water dependent it is questioned whether circulation of a well after treatment down the annulus is beneficial. Some organic corrosion inhibitors are believed to accelerate corrosion at low concentrations.

A new task group organization has been made by the committee. 11313

8.4.3

The Selection of Materials for Some Petroleum Refinery Applications. J. F. MASON, JR. *Corrosion*, 12, No. 5, 199-206 (1956) May.

Extensive tabulated data with accompanying discussions are devoted to quantitative information on the performance of various ferrous and non-ferrous alloys in refinery service. The sixteen tables of data from the records of the Corrosion Engineering Section of The International Nickel Company, Inc., give results of actual service tests with ASTM spool-type specimens.

When sour crudes are charged, corrosion in the atmosphere crude distillation system is maximum in the tops of vessels. Results of tests above the top plate indicate Monel suitable as a cladding or lining material. When sweet crude is charged little corrosion is encountered. In reflux water separators where water is free of hydrogen chloride or contains some hydrogen chloride as well as hydrogen sulfide, nickel or copper-base alloys are suitable.

It is customary to use Admiralty metal, 70-30 Cupro-Nickel or Monel for gasoline condenser tubes and coolers. The degree of acidity of the condensate and condition of the cooling water will determine which of these materials will be used in a given application.

Austenitic stainless of Types 302, 304 and 316 and ferritic stainless resist the high temperatures and sulfur conditions at the bottoms of towers. These materials also are used in bubble caps.

For vapor separators and fractionation towers the 4-6 percent chromium steels have demonstrated superiority.

Alloys are required in regenerators of caustic soda solutions, for reboilers and tubes, as lining in bottom sections and for piping and preheaters. Monel and Inconel resist corrosion in these environments.

Tabulated results are given of tests in equipment used in acid treatment of lubricating oils. Materials found good for pumps and valves are Monel and the nickel-chromium-molybdenum alloys. In sulfuric acid alkylation mild steel is satisfactory except where high velocity or turbulence is encountered as in pumps, valves or return bends. Types 304 or 316 stainless are satisfactory. In separator tanks where diluted acids are encountered, especially when agitated with live steam, there should be a brick lining with metal support of Duriron, Corrosiron, Hastelloy D or Illium.

In hydrofluoric acid alkylation plants most corrosion is encountered in acid regeneration units and the acid dehydration column. Monel or 70-30 cupro-nickel alloys are found satisfactory. In furfural recovery systems Monel gives good service. 11281

8.4.3, 5.2.1

Surface Pipe Effect—Cathodic Protection of Oil Well Casing. JACK P. BARRETT. *Corrosion*, 11, No. 10, 415-416 (1955) October.

Potential profile curve shows abrupt anodic slope at base of surface pipe. Graph, photograph.—BTR. 11324

8.4.3, 5.8.2

Iron in Oil Technique as a Corrosion Control Criterion. R. G. RYDELL AND W. H. RODEWALD. *Corrosion*, 12, No. 6, 271-276 (1956) June.

A discussion of existing corrosion criteria is made. The need is pointed out for short term control to supplement present long term studies, especially where existing short term methods are questionable or not applicable.

Iron was found in the oil phase of produced fluids and was found present in particle form. Average values of from 25-150 ppm were determined with extreme varying from trace amounts to 2500 ppm.

Development of a technique to determine the amount of iron in the oil to simplify determinations was made. Trial methods which led to final Walker-Robertson technique are outlined and the technique is described in detailed form.

Evaluation studies were made on 94 sour wells which were using various corrosion inhibitors. Utilizing the iron in oil technique, correlation studies showed that a break point value of 55 ppm existed between economically corrosive and non-corrosive wells. Further studies in the Kansas area substantiated the findings with regard to the 55 ppm break-point. The dividing line between wells which are corrosive and those under good corrosion control may vary depending on the area. It is suggested that further work be done with this criteria of corrosion control to determine if applicable to various types of wells in various areas. 11485

8.4.3, 5.8.2

Field Practices for Controlling Water-Dependent Sweet Oil Well Corrosion. A Report of Technical Unit Committee on Sweet Oil Well Corrosion. H. E. GREENWELL, Chairman. (Compiled by Task Group T-1C-1 on Field Practices. J. T. Payton, Chairman.) *Corrosion*, 12, No. 3, 149-153 (1956) March.

Field practices used by 19 companies for controlling corrosion in water-dependent sweet oil wells are reported. Limits at which corrosion becomes detrimental are given in terms of percent water produced, iron concentration, coupon corrosion rate, percent wall reduction and frequency of equipment failure. Reports are given of the use of the following devices on flowing wells: injection valves, sidedoor chokes, tapered tubing and special equipment. Consideration is given also to the minimizing of corrosion in gas lift wells and in pumping wells.

Accounts of the use of plastic coated and special alloy tubing are given. Other topics discussed include the use of liquid inhibitors, weighted inhibitors, stick inhibitors, pellet form inhibitors, inhibitor choke and special techniques. 11027

8.4.3

Research as Applied to Some Metallic Materials for the Petroleum Industry. B. B. MORTON. *Mines Mag.*, 45, No. 10, 115-118, 128 (1955) Oct.

Outlines some of the research carried on by Inco for the petroleum industry and resulting uses made of the data. Discussed are the development of K

odic Pro-
JACK P.
0, 415-416

ws abrupt
face pipe.
11324

Corrosion
DELL AND
12, No. 6,

osion crite-
ed out for
ent present
here exist-
questionable

ase of pro-
present in
f from 25-
h extreme
2500 ppm.
to deter-
oil to sim-
ade. Trial
alker-Rob-
the tech-
orm.

ade on 94
arious cor-
iron in oil
nowed that
existed be-
and non-
tes in the
e findings
break-point.
which are
l corrosion
n the area.
rk be done
control to
ious types
11485

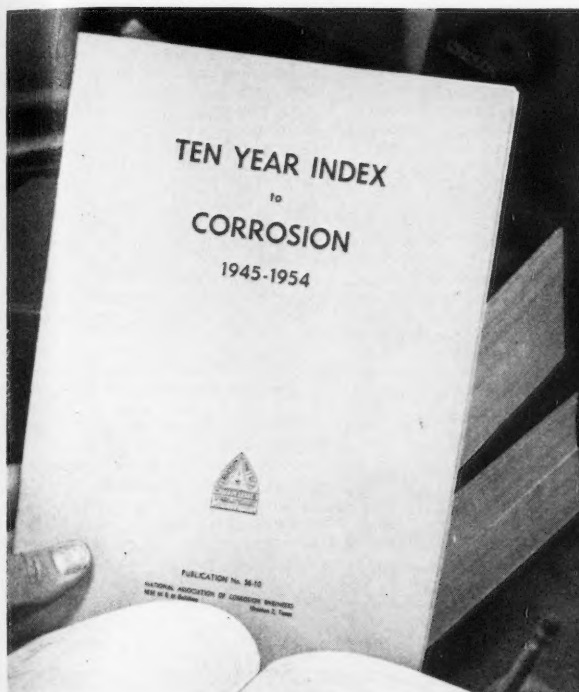
ng Water-
Corrosion.
Committee
on. H. E.
ed by Task
ices. J. T.
12, No. 3,

panies for
-dependent
Limits at
mental are
produced,
osion rate,
frequency of
given of
on flowing
or chokes,
equipment,
e minimiz-
ells and in

stic coated
ven. Other
e of liquid
tick inhib-
bitor choke
11027

e Metallic
Industry.
5, No. 10,

ch carried
a industry
the data-
ent of K



1056 Authors Help You Solve Your Corrosion Control Problems



4000 REFERENCE PHRASES to 3591 Pages of Technical Literature

what you will find in the Index:

A carefully compiled, conscientiously arranged and properly printed key to the wealth of engineering information published in the NACE monthly journal CORROSION. Only Technical Section pages are covered.

4000 reference phrases, more than one reference per page of text

629 titles to articles arranged chronologically and by page number

1056 authors' names, referenced to articles and discussions

- Liberal cross-referencing
- Discussions cross-referenced to articles
- Errata cross-referenced
- NACE Abstract Filing System Index terminology used as basis
- Volume and year included in chronological, subject and author's lists

TEN YEAR INDEX to CORROSION 1945-1954



NACE Publication
No. 56-10

Please send postpaid to the person named below copies of the Ten Year Index to Corrosion as indicated. (Please typewrite or print.)

Name _____	
Number _____	Street _____
City _____	
Zone _____	State _____

Copies at \$ _____	
each _____	\$ _____
Registry Fee*	\$ _____
Total _____	\$ _____
Prices:	
NACE Members, copy	\$5.00
All Others	\$7.50

Send with remittance
if possible to
**NATIONAL ASSOCIATION
of
CORROSION ENGINEERS**
1061 M & M Bldg.
1 Main St. Houston 2, Texas

fill in and mail this coupon ➔

* Add 65c for Book Post Registry to all addresses outside of the United States, Canada and Mexico.



J. M. PEARSON

Contributions of J. M. Pearson to Mitigation of Underground Corrosion

Six articles by the late Dr. J. M. Pearson and one by an associate prepared under his leadership are reprinted for the information of new workers and established investigators into underground corrosion problems. Dr. Pearson, recipient of the 1948 NACE Speller Award for achievements in corrosion engineering, is recognized for his outstanding work on problems associated with corrosion of metals underground. The articles, originally published during 1941-44 in *The Petroleum Engineer* and in *Transactions of The Electrochemical Society* are reprinted by permission in this book dedicated to him.

Papers included are:
Electrical Examination of Coatings on Buried Pipelines
"Null" Methods Applied to Corrosion Measurement
Determination of the Current Required for Cathodic Protection
Concepts and Methods of Cathodic Protection, Parts I, II and III
Preventive Maintenance by Systematic Pipeline Inspection by Donald F. Van de Water

56 pages, 8½ x 11 inches, paper cover.
1956. NACE Publication 56-12. Per copy, postpaid.

\$5

Add 65 cents per copy for book post registry to all addresses outside the United States, Canada and Mexico.

**NATIONAL ASSOCIATION OF
CORROSION ENGINEERS**
1061 M & M Building
Houston, Texas

Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount of U. S. funds.

Monel non-magnetic drill collars, Inco sea water corrosion studies and resistance of Monel as applied to offshore petroleum problems, use of 9 nickel steel for tubing in sweet distillate wells and study of hydrogen sulfide corrosion in sour distillate wells, effects of hydrogen on steels, use of corrosion test spool for in situ testing in petroleum and petrochemical industries, development of 9 nickel steel for use in liquid air temperatures, use of Monel and Inconel for resisting caustic and sulfur compounds, development of metals for high temperatures and high pressures (Inconel X) and the importance of cooperation between laboratory and field. Graphs show effect of nickel content on low temperature embrittlement resistance of normalized low carbon steels and elevated temperature rupture properties of nickel-containing alloys and steels.—INCO. 10913

8.4.5

Metallurgical Problems in Design of Nuclear Power Reactors. VINCENT P. CALKINS. General Electric Co. *Metal Progress*, 68, No. 6, 73-76 (1955) Dec.

A general discussion is given of factors which limit the selection of materials for use in nuclear reactors. Such factors include radiation damage, neutron absorption characteristics and corrosion effects. The role of powder metallurgy in the fabrication of reactor materials is also discussed.—NSA. 11392

8.4.5

Materials for Atomic Plants. B. R. ELDER. *Gen. Elec. Rev.*, 58, No. 6, 38-41 (1955) November.

Functional tour of an atomic installation similar to the Hanford Atomic Products Operation, emphasizing criteria involved in materials selection. Material usage is divided into three categories: Water plant, reactor plant and separations plant. Carbon steel, cast iron, austenitic (300 series) stainless steel and aluminum are the principal structural metals, while graphite and concrete are the principal structural non-metals. In reactor plants, aluminum and zirconium are excellent structural materials for use where neutrons are to be conserved. Boron, cadmium and gadolinium qualify as excellent control materials. Typical materials for separations plant service are Types 304 extra-low carbon or 347 austenitic stainless steel. Illustrations.—INCO. 11483

8.4.5

Metals for Nuclear Plants. E. H. KRIEG. Paper before Forum on Atomic Opportunities in New England, sponsored by New England Council and Atomic Industrial Forum, Inc., Boston, October 20, 1954. Atomic Opportunities in New England Forum Report, June, 1955, 36-52.

Discusses several metals used in nuclear plants and some of their applications with a view to the mining, vacuum melting, manufacturing and atomic research and development opportunities in New England. Availability, production methods, specific properties and uses of titanium, zirconium, beryllium, aluminum and vanadium and irradiation effects, high temperature effects, creep, corrosion and oxidation resistance of metals are considered. A thermocouple for measuring reactor fuel element temperatures, made of an Inconel tube surrounding a copper-nickel-manganese alloy wire, is cited. Inconel tube eliminates need for a protective covering. Heat treatment of austenitic stainless steel

(most important alloy available for plants operating at 1050 F and over) is discussed. Future cost of power generated depends on how stainless steels are improved. Seven out of eight turbine generators on which there is information, developed cracks in 18-8 piping, forgings and castings. Numerous tables list mechanical and physical properties of reactor materials (including nickel, 18-8 and Inconel), nuclear properties of structural materials, moderators, heavy-aggregate concretes and coolants and thermal and fluid properties of coolants. Failure of high temperature turbine belts made from an age hardening steel is mentioned.—INCO. 10987

8.4.5

Reactor Materials to Do a Tough Job. H. C. SCHWENK AND R. H. SHANNON. *Power*, 99, No. 9, 98-100, 198, 200 (1955) September.

Discusses fuel materials, requirements for structural, cladding, piping and containment materials, corrosion and mass transport, thermal transients, design codes, coolants, thermal and electrical insulation and shielding. Types 304, 316 and 347 are used for cladding, reactor components and coolant systems.—INCO. 10986

8.4.5

Nuclear Energy Today. L. N. ROWLEY AND B. G. A. SKROTZKI. *Power*, 99, No. 12, 73-96 (1955) Dec.

Briefly reviews fundamentals on how nuclear reactors work and summarizes developmental and commercial-scale nuclear projects—the equipment, advantages of various designs, and problems that remain. Pressurized-water reactor (PWR), boiling water reactor, sodium-graphite reactor, fast breeders, and homogeneous reactors are described. Because uranium corrodes easily, fuel elements must be completely clad with zirconium, stainless steel or aluminum. Radioactive gases produced by fissioning also necessitate canning or cladding of fuel elements. Zirconium, stainless steel and Stellite are used to contain highly corrosive high purity water. In PWR, all surfaces of U-235 zirconium-alloy in reactor core are clad with Zircaloy-2 to guard against corrosion. Zircaloy-2 tubes filled with uranium dioxide pellets make blanket assemblies. The steam turbine has stainless steel lining in cylinder barrel between blade rows. All blades are Stellite faced. Fuel slugs of fast breeder reactor are U-235 in stainless steel cans. Numerous structural diagrams of reactors are shown. Table summarizes stationary power reactors currently planned or under construction.—INCO. 10971

8.4.5

Corrosion. A. H. ROEBUCK. Paper from *The Reactor Handbook*, Vol. II. Engineering (Tech. Inf. Service, U. S. Atomic Energy Comm.), Pubn. AEC-D-3646, 1955, 193-233. Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Selection of materials for water-cooled reactor systems involves establishing the effect of environment on corrosion of material and the effect of contamination by that material on the environment. Photographs, graphs, tables, 128 references.—BTR. 10970

8.4.5

Homogeneous Nuclear Reactor. R. HURST. *Research*, 8, 301-306 (1955) Aug.

PREVENTIVE MEASURES, CA

Partial protection is also very desirable in many cases involving poorly coated lines and can be justified by reductions in sinking fund deposit factors due to increased pipe life, in addition to usual savings in operations.

Electrical engineers should anticipate that cathodic protection will effect savings in other corrosion areas. Power plant equipment, cables, substations, docks, ships and other situations involving metals in contact with soils and solutions are fertile fields for the application of cathodic protection and modern techniques of corrosion control

5.2.1-56 CORROSION CONTROL OF STEEL EQUIPMENT. T. R. B. Watson. *Can. Chem. Processing*, 37, No. 10, 46, 48, 50, 52, 54 (1953) Sept.

Describes causes of corrosion and discusses control by means of cathodic protection.

5.2.1-57 CATHODIC PROTECTION LICKS CORROSION. L. C. Werkin. *Petroleum Refiner*, 31, No. 9, 122-124 (1952) Oct.

Cathodic protection, a positive, controllable and inexpensive method of preventing corrosion. There is real money in reducing these losses caused by corrosion-maintenance, replacement costs, over-design of equipment, and product losses. Refinery management and technical personnel must be keenly aware of the creeping inroads of corrosion, and alert to any feasible solution to the problem. Table showing cost estimates and savings resulting from its use on a large open-box-type refinery condenser and a large diameter Dorr clarifier. 9 refs.

CATHODIC PROTECTION OF STEEL. F. Nurse, H. C. K. Ison and T. W. Farrer. *Corrosion*, No. 40, 972-974 (1952) Oct. 4.

Current and potential requirements for steel in sea water and in the presence of mild steel in sea water. Stages at a relatively noble potential are sufficiently high, through a steel anode. If a small current is present, the presence of the

PRICES

NACE Members
\$10

Non-Members
\$12.50

Pages 382
Page size 8 1/2 x 11
No. Abstracts
3344
Binding
Hard Cloth

Buy More Than One Volume
and **Save 10%**

MORE THAN 15,000 articles on corrosion and corrosion prevention have been referenced in the five Bibliographic Surveys published to date. If you are concerned with corrosion work, consider buying more than one volume and save 10%. (This does not apply to more than one copy of the same volume.)

1950-1951 volume, containing 4454 abstracts, NACE members **\$10**
(Non-members \$12.50)

1948-1949 volume, containing 3512 abstracts, NACE members **\$10**
(Non-members \$12.50)

1946-1947 volume, containing 3362 abstracts, NACE members **\$ 7**
(Non-members \$9)

1945 volume, containing 1086 abstracts, NACE members **\$ 4**
(Non-members \$5)

Now Available

1952-53

BIBLIOGRAPHIC
SURVEY
of

CORROSION

C
m
pr
A
sis
redu
ing

1.6-3, 4;
4.5.1-1; 4.5.3-
6.3.8-6; 7.2-17,
44; 8.4.2-8; 8.4.3-
8.9.5-12

5.2.2 PREVENTIVE
PROTECTION, AND

a. General
b. Magnesium

5.2.2-1 CATHODIC PROTECTION OF ANODES. Brochure, June, 1953
tute, 60 East 42nd Street, New

Merits of zinc anodes (combined with rectified systems) in reducing distribution piping, transformers, condensers. Practical

Intended as
Galvanic

5.2.2-2
TANK
49 (19
A y
nesium
of

Topically Arranged
Topically Cross-Indexed
Alphabetically Indexed
Author Index

Find Published Information Easily

Each reference gives complete information for obtaining a copy of the original article. Arrangement of material and indexing facilitate searching. Domestic and foreign periodicals, books and other literature are covered.

Send orders and remittances to

NATIONAL ASSOCIATION
of
CORROSION ENGINEERS

1061 M & M Bldg.

Houston 2, Texas

• Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount of U. S. funds.

• In addition to the prices shown there is a charge of \$.65 per package for sending volumes by registered book post to addresses outside the United States, Canada and Mexico.

INDEX TO ADVERTISERS

Vol. 12 November, 1956 No. 11

	Page
Alloy Steel Products Company, Inc.	1
Amercoat Corporation	Inside Front Cover
American Hot Dip Galvanizers Association, Inc.	116
Anacosta Wire & Cable Company	7
Apex Smelting Company	87
Aquasess Department of Atlas Powder Company	144
Barrett Division, Allied Chemical and Dye Corp.	Facing Page 144
Calgon, Inc.	9
Carboline Company	82
Catholic Protection Service	97
Colorado Fuel and Iron Corporation, The	10, 11
Columbia-Southern Chemical Corp.	13
Copon Associates	12
Corrosion Engineering Directory	131
Corrosion Rectifying Company	80
Corrosion Services, Inc.	78
Crest Instrument Company	98
Curtiss-Wright Corporation	137
DeVilbiss Company, The	15
Dow Chemical Company	2
Dowell Incorporated	79
du Pont de Nemours, E. I. & Co., (Inc.)	103
Duriron Company, Inc.	Inside Back Cover
Electro Rust-Proofing Corporation	101
Fisher Research Laboratory, Inc.	84
Good-All Electric Manufacturing Co.	86
Haveg Industries Corporation	89
Humble Oil & Refining Company	81
Inertol Co., The	96
International Nickel Company, Inc., The	93
International Paint Company, Inc.	92
Johns-Manville Sales Corp.	105
Kellogg, M. W. Company	95
Kerr Chemicals, Inc.	124
Koppers Company	111
Luzerne Rubber Company, The	104
Maloney, F. H. Company	115
Mayes Brothers, Inc.	102
Metal and Thermit Corporation	
United Chromium Division	14
Midwestern Pipe Line Products Company	113
Minnesota Mining & Manufacturing Co.	125
Mutual Chemical Division	
Allied Chemical & Dye Corporation	107
National Association of Corrosion Engineers	80, 90, 100, 110, 120, 135, 139, 140, 141
National Carbon Company, Division of Union Carbide & Carbon Corp.	121
Norris, R. S. & Associates	133
Pittsburgh Coke and Chemical Co.	Back Cover
Plicoflex, Inc.	109
Positions Wanted & Available	106
Reilly Tar & Chemical Corporation	117
Resistoflex Corporation	90
St. Joseph Lead Company	129
Shawinigan Resins Corporation	143
Smith, Nowery J., Galvanizing Company	8
Spee-Flo Corporation	5
Standard Magnesium Corporation	123
Tapecoat Company, The	119
Texteam Corporation	122
Thornhill-Craver Company	146
Tropical Paint Company	88
Tube Turns Plastics, Inc.	134
United Chromium Division, Metal and Thermit Corporation	14
United States Stoneware Company	85
Wholesale Coke Company	94
Wickwire-Spencer Steel Division, The Colorado Fuel and Iron Corporation	10, 11
Wilbur & Williams Company	127
Williams, T. D., Inc.	128

Advantages and disadvantages of the homogeneous reactor as a power source are discussed. The greatest advantage is the possibility of continuous removal of fission products from the reactor, whereas problems of minimizing corrosion and contamination appear to be the chief disadvantages. Fluid fuel reactor development is outlined.—NSA. 10936

8.5 Group 5

8.5.3, 7.6.6

Field Investigation of Corrosion in Alkaline Pulp Equipment. C. B. CHRISTIANSEN AND J. B. LATHROP. *Tappi*, 38, 122-128 (1955) Feb.

Forces which cause corrosion in digesters, recommendations for extending service life of alkaline pulping equipment. Diagrams, graphs, table.—MR. 11442

8.6 Group 6

8.6.1

Aluminium as a Laundry Material. (In French.) CHARLES ETIENNE. *Rev. Aluminium*, 33, No. 228, 60 (1956) Jan.

It is stated that aluminum is the ideal construction material for laundry equipment for the following reasons: 1) aluminum, its oxide and its salts do not stain the clothes; 2) it does not tear and wear the clothes; 3) its good heat conductivity reduces condensation to a minimum and permits the fast heating up of drying and ironing devices and 4) it is lightweight, easily machined and requires no maintenance. Two representative pieces of laundry equipment are pictured and it is said that the permanently humid atmosphere of the laundry has no effect whatsoever on the alloys recommended for this purpose such as A5, A-G1, A-G3, A-SG and A-Z4G.—ALL. 11339

8.6.3, 6.2.5, 3.2.2, 5.8.2

Severe Pitting of Stainless (18-8) Steel in Hot Chloride Dye-Baths: A Technical Note. F. N. SPELLER. *Corrosion*, 11, No. 7, 303t (1955) July.

Pitting in welded and cast stainless dyeing equipment was caused by hot aerated salt water in dye bath. Action was highly localized at welds or in exposed porous spots in castings, leading to stress-corrosion cracks and carbide precipitation. Photomicrographs.—INCO. 10642

8.7 Group 7

8.7.3, 6.3.10, 6.2.5

The Role of Nickel and Nickel Substitutes in Jewelry Making. K. H. MAIRS AND J. M. WILLIAMS. *Corrosion*, 12, No. 3, 113t-118t (1956) March.

Numerous laboratory tests are reported of couples between 24 and 10 karat gold, sterling silver, 800 silver, 430 stainless iron, composition, 10 percent nickel silver, 18 percent nickel silver, aluminum bronze, LC nickel and 305 stainless steel in both acid and alkaline synthetic perspiration. Expected potential difference occurred between the materials and gold. Type 305 stainless steel showed the least tendency to corrode with the copper base alloys showing the greatest tendency toward corrosion. Potentials in acid perspiration were greater than those in alkaline.

The authors conclude alloys which develop protective films are more satisfactory than those which do not. Resistance of nickel is not entirely satisfactory but no

single substitute has the general usefulness of nickel. Under many conditions Type 430 stainless iron is not sufficiently resistant to be useful in jewelry making. 11155

8.8 Group 8

8.8.1, 1.2.2

Corrosion Damage in the Hungarian Chemical Industry. (In Hungarian.) KLARA KOVACS. *J. Hungarian Chem. Soc. (Magyar Kemikusok Lapja)*, 10, No. 10, 306-309 (1955) October.

Evaluation of the data collected for 1953 by the Corrosion Observation Service; damages and costs and methods of combating damage. Tables. Five references.—BTR. 11444

8.8.3

Electroplating Equipment. R. ALLEN. *Metal Industry*, 86, No. 6, 107-110 (1955) February 11.

This article, one of a series describing the British electroplating industry, is devoted to the basic requirements in electroplating. Details are given of tank materials and linings available, together with the various methods of heating. Transformer rectifier sets are preferred to low voltage generators for the supply of the low voltage direct current required for electroplating processes. A table giving the recommended current ratings for conductors is also provided.—ZDA. 11352

8.9 Group 9

8.9.4, 1.2.2

Corrosion—A \$400,000,000 Millstone to the Railroad Industry. J. W. CROSSETT. *Modern Railroads*, 10, No. 12, 113, 115-116 (1955) Dec.

Discusses the importance of corrosion in railroad industry and efforts being made to reduce its effects. Cost of corrosion during 1953 is estimated at \$410,000,000. Cost directly attributed to brines in refrigeration cars is \$12,000,000 per year. Preventive measures include use of inhibitors in brine solutions, control of pH and use of inhibitors in cooling water system of diesel locomotives, proper surface preparation, primer and top coats, metallic coatings, cathodic protection and use of more corrosion resistant materials as high-strength low-alloy steels and stainless steels. Photographs show rusted sills and posts on diner, corrosion damage and heavy rust on hopper cars, cavitation erosion of Diesel locomotive cylinder jacket and deleading of Diesel bearing.—INCO. 11285

8.9.1, 1.6

Strength of Metal Aircraft Elements. U. S. Department of the Air Force, of the Navy and of Commerce, Bulletin ANC-5, March, 1955 (revised edition), 180 pp. U. S. Govt. Printing Office. Washington 25, D. C.

This useful publication contains data approved for use in calculating allowable stress or minimum strengths of aircraft structures. Includes commonly used formulae, theory and chapters on steel, aluminum alloys, magnesium alloys, titanium and miscellaneous metals. These deal with mechanical properties at room, low and elevated temperatures; design of columns and beams, torsional failure and joints. Materials are referred to by their U. S. designations.—BNF. 10989

usefulness
tions Type
ntly resist-
ing. 11155

Hungarian
ngarian.)
Chem. Soc.
10, No. 10.

llected for
ation Serv-
methods of
Five refer-
11444

R. ALLEN
-110 (1955)

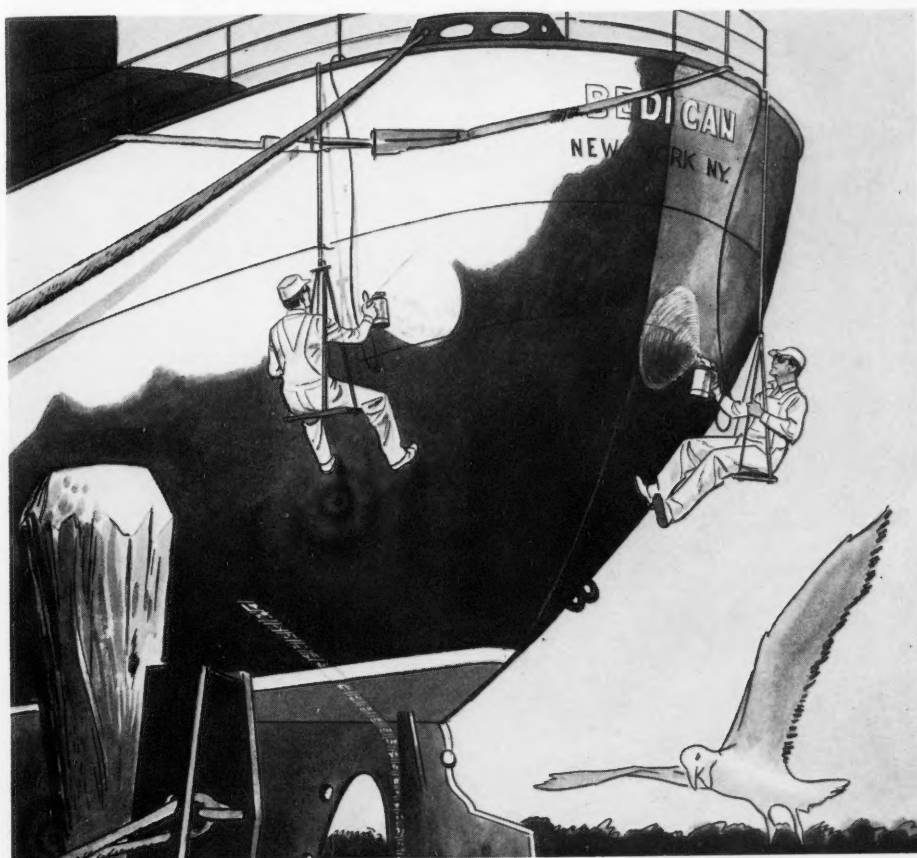
s describing
stry, is de-
s in electro-
nk materials
with the vari-
ormer recti-
tage genera-
low voltage
electroplating
ecommended
is also pro-
11352

Millstone to
W. CROSSETT.
2, 113, 115-

of corrosion
orts being
st of corro-
at \$410,000-
to brines in
00 per year.
se of inhibi-
of pH and
water system
surface prep-
ts, metallic
and use of
ials as high-
nd stainless
ted sills and
damage and
vitation ero-
inder jacket
ing.—INCO.
11285

t Elements.
ir Force, of
ce, Bulletin
ed edition),
ing Office.

contains data
ating allow-
trengths of
commonly
chapters on
magnesium al-
eous metals.
l properties
temperatures;
is, torsional
are referred
ions.—BNF.
10989



proved corrosion resistance with wash primers

The adhesive properties of Shawinigan Resins' FORMVAR and BUTVAR are especially valuable in "wash primers." Anti-corrosion primers of this type adhere better on metal surfaces and permit better adhesion of top coat to primed surfaces. This tenacious two-way adhesion provides better protection against corrosion.

These primers or metal conditioners have other important advantages over conventional materials. They apply easier, dry faster, resist abrasion and impact, and prevent underfilm corrosion. The wash primer protective coating of only 0.3 to 0.8 mil thickness is a tough, corrosion resistant conditioner for steel, aluminum, cadmium, tin, galvanized

iron and magnesium. Formulation is easy in your regular pebble mill.

Wash primers have extended the life of metals in many applications and have opened profitable new markets for paint manufacturers. For full technical information, resin samples and suggested formulations, write Shawinigan Resins Corporation, Department 2711, Springfield 1, Massachusetts.



FORMVAR® and BUTVAR® resins by



Engineered corrosion control

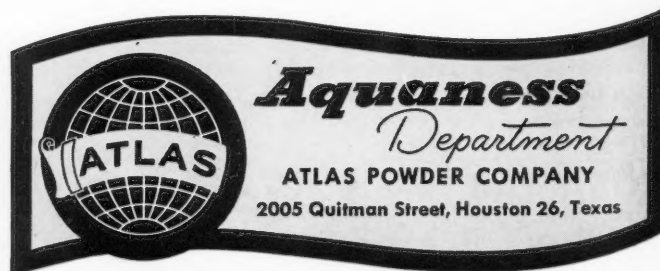
Write today for the new booklet,
"Aquaness—producers of chemicals for the oil industry".



Engineered corrosion control—the combination of thorough Aquaness service and experience, plus Cronox corrosion inhibitors—provides the *surest* protection for your tubing, rods, flow lines, pumps and other equipment . . . at lowest cost.

Cronox corrosion inhibitors put a tough, microscopic, corrosion-resistant film on metal surfaces. And the Aquaness field men, long experienced in the corrosion problems of the petroleum industry, will give the thorough, painstaking service that's required to solve your corrosion problems.

In the field or in the refinery, you'll find Aquaness Engineered Corrosion Control to be the best combination for your needs.



ALL-AROUND PROTECTION

You get all-around pipe protection with Barrett Pipeline Felt. This strong asbestos felt thoroughly impregnated with high-grade coal tar saturants is a tough, durable flexible wrapper that forms a perfect bond with Barrett Enamel. The result is lasting protection at minimum cost. This you are assured by the assistance of the Barrett Technical Service Group. Write for complete information.

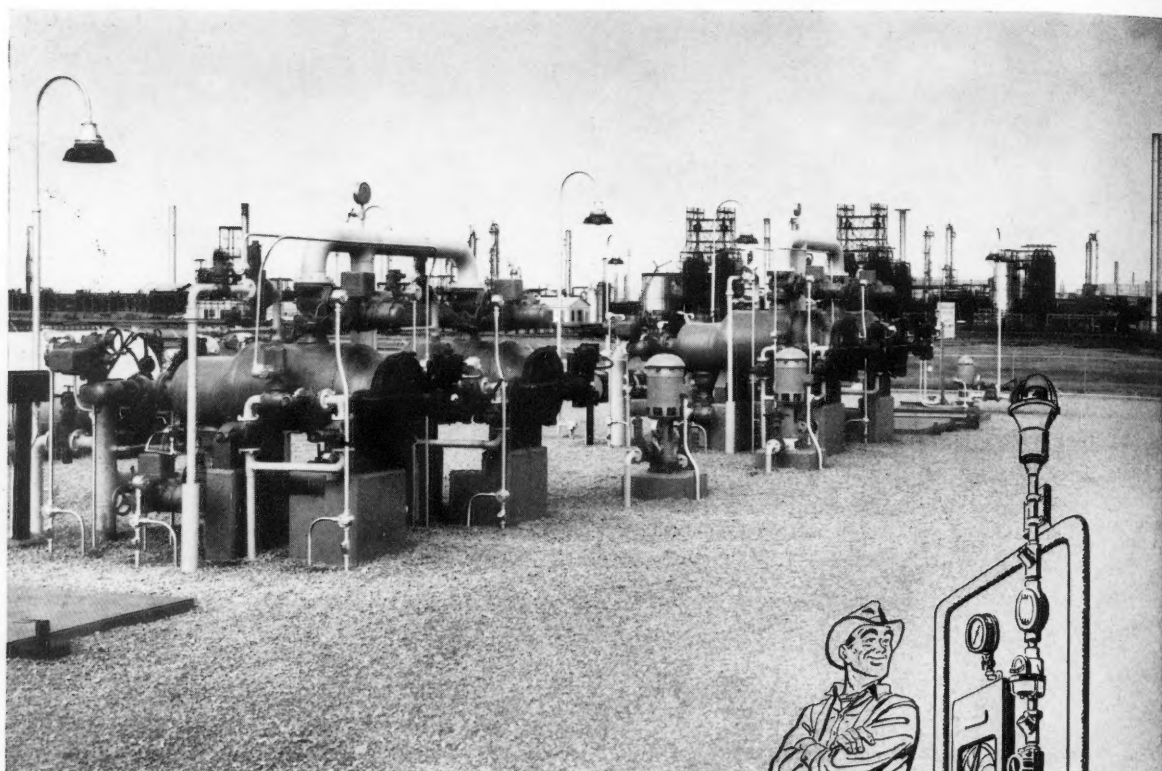
Experienced applicators of Barrett materials are available for field or special work throughout the country.



PROTECTIVE COATINGS

BARRETT DIVISION, Allied Chemical & Dye Corporation, 40 Rector St., N. Y. 6, N. Y. In Canada: The Barrett Company, Ltd., 5551 St. Hubert Street, Montreal, Que.
OVER 100 YEARS OF EXPERIENCE





How to filter refined pipeline products

...without so much
as lifting a finger!

Jet Strainers offer three distinct advantages over all others:

(1) They strain all of the product . . . all the time, requiring minimum stand-by capacity. This means that it is never necessary to by-pass any of the dirty product. Thus, metal seals, bearings and other vulnerable pump parts cannot be damaged by solids entrained in the product. Metering equipment is likewise protected against damage.

(2) Jet Strainers filter the product to any desired degree. Stainless steel strainer baskets are available in mesh sizes up to 400. Filter-aids may be used to further improve the brightness of the product.

(3) Since Jet Strainers are self-cleaning, automatic controls may be applied to the strainers to make their operation fully automatic if desired. Even semi-automatic Jet

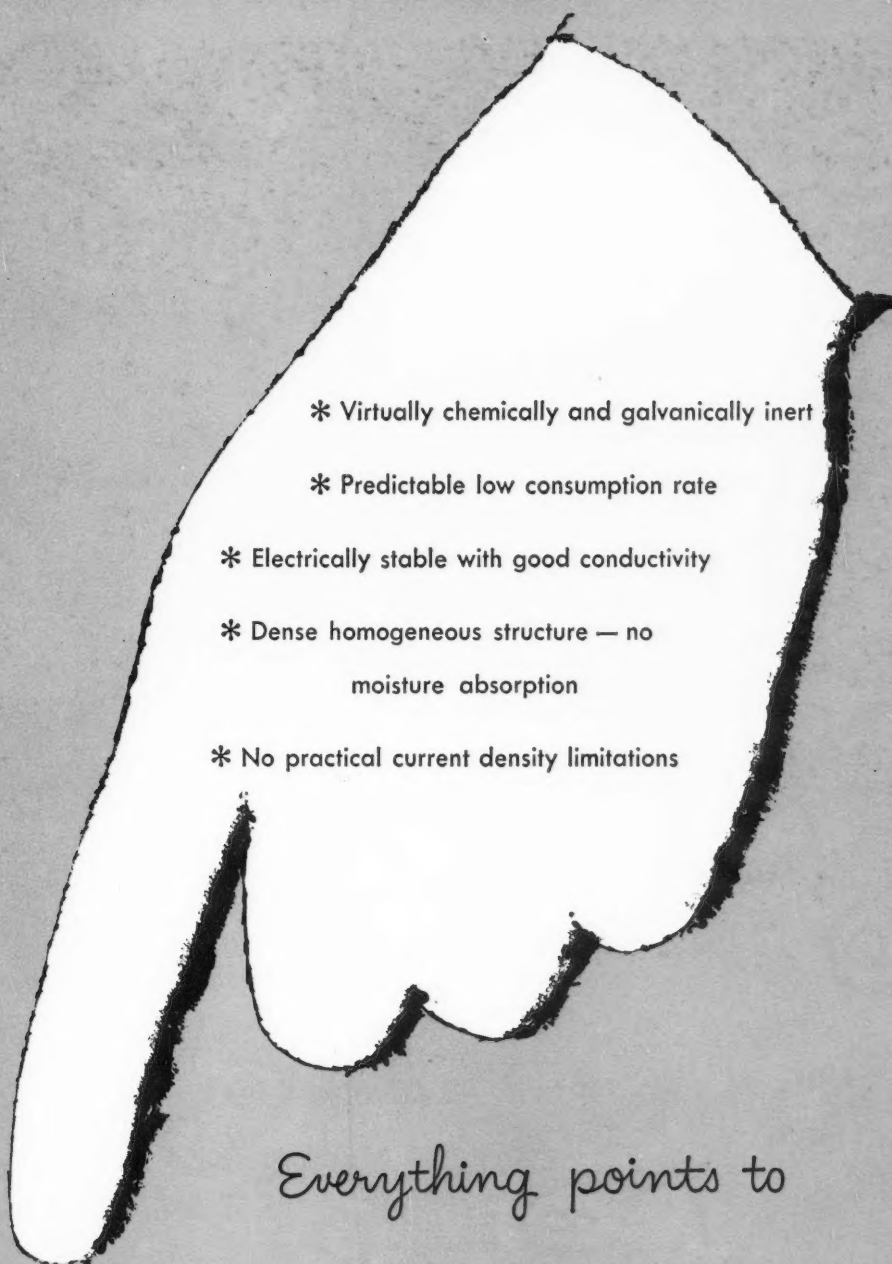
Strainer operation reduces the process to push-button control and manual opening and closing of a few valves.

The whole story on Jet Strainers has been prepared in booklet form. A copy will be sent gladly on request.

THORNHILL-CRAVER CO.
P. O. BOX 1184 HOUSTON, TEXAS

JET STRAINER

*Strains all the product
...all the time*



* Virtually chemically and galvanically inert

* Predictable low consumption rate

* Electrically stable with good conductivity

* Dense homogeneous structure — no
moisture absorption

* No practical current density limitations

Everything points to

DURIRON[®]

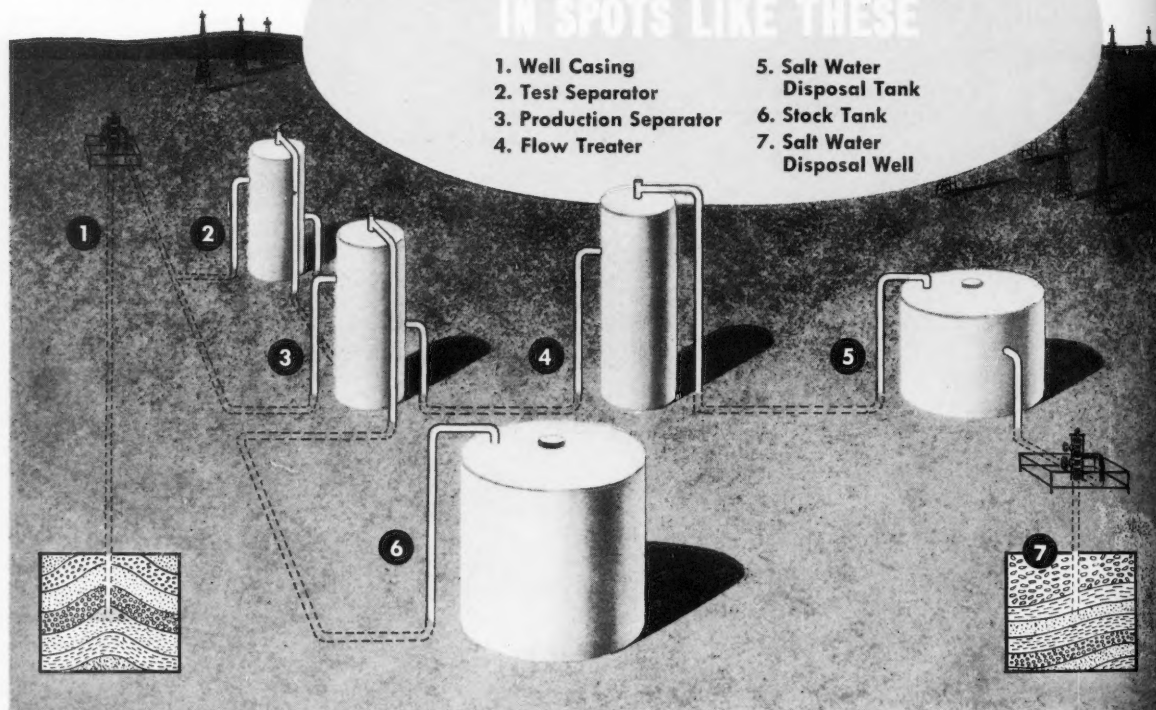
Impressed Current

ANODES *for cathodic protection*



THE DURIRON COMPANY, Inc. / Dayton, Ohio

HOW TO PREVENT *Crude Oil Corrosion* IN SPOTS LIKE THESE



...WITH **TARSET**[®]

HERE'S an important new weapon for controlling costly crude oil corrosion. It's **TARSET**—the effective new *coal tar-epoxy resin* coating. In test after test, Tarset has proved that it can stop corrosion caused by sour crude in storage tanks and in a growing number of other pieces of crude oil handling equipment.

Tarset is the toughest, hardest coating of its kind ever produced from coal tar. It will not shatter at -30°F . or soften at 400°F . It is

superior to all other coal tar coatings in its ability to adhere to metal and concrete. And Tarset is easy to apply by brush, roller or spray.

If you have a corrosion problem—above ground or below—call on *Pittsburgh*. Without obligation, our engineers will gladly tackle your specific crude oil corrosion problem . . . and come up with dollar-saving answers. Let us hear from you today.



Send for Descriptive Booklet on **TARSET** today

Free booklet tells how to use amazing new Tarset to reduce costly corrosion. Gives detailed description of Tarset's specifications, properties and application characteristics. Write for *your* copy today!



